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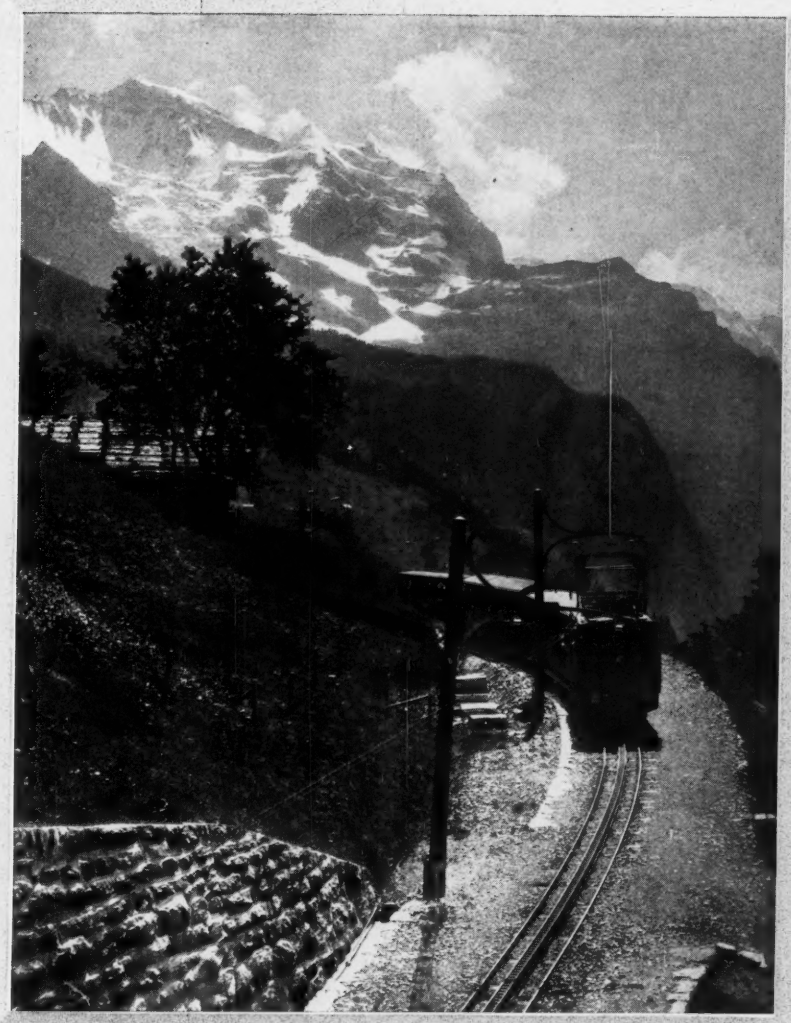

MASSACHUSETTS
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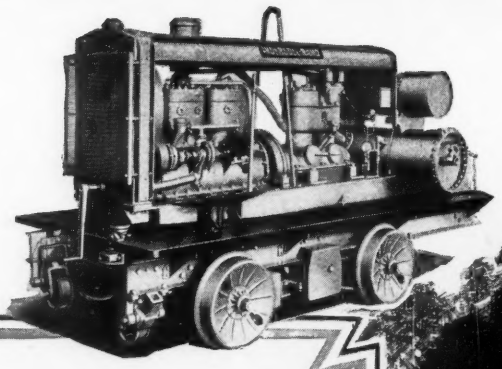
FEBRUARY, 1930



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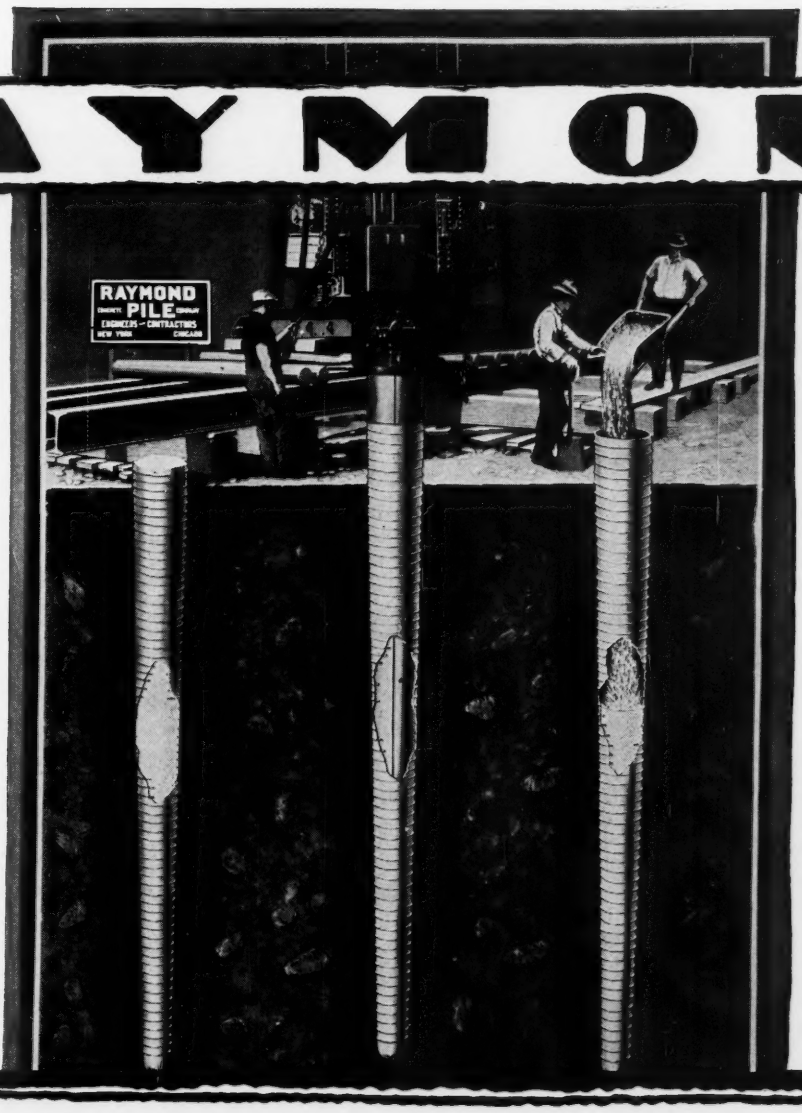

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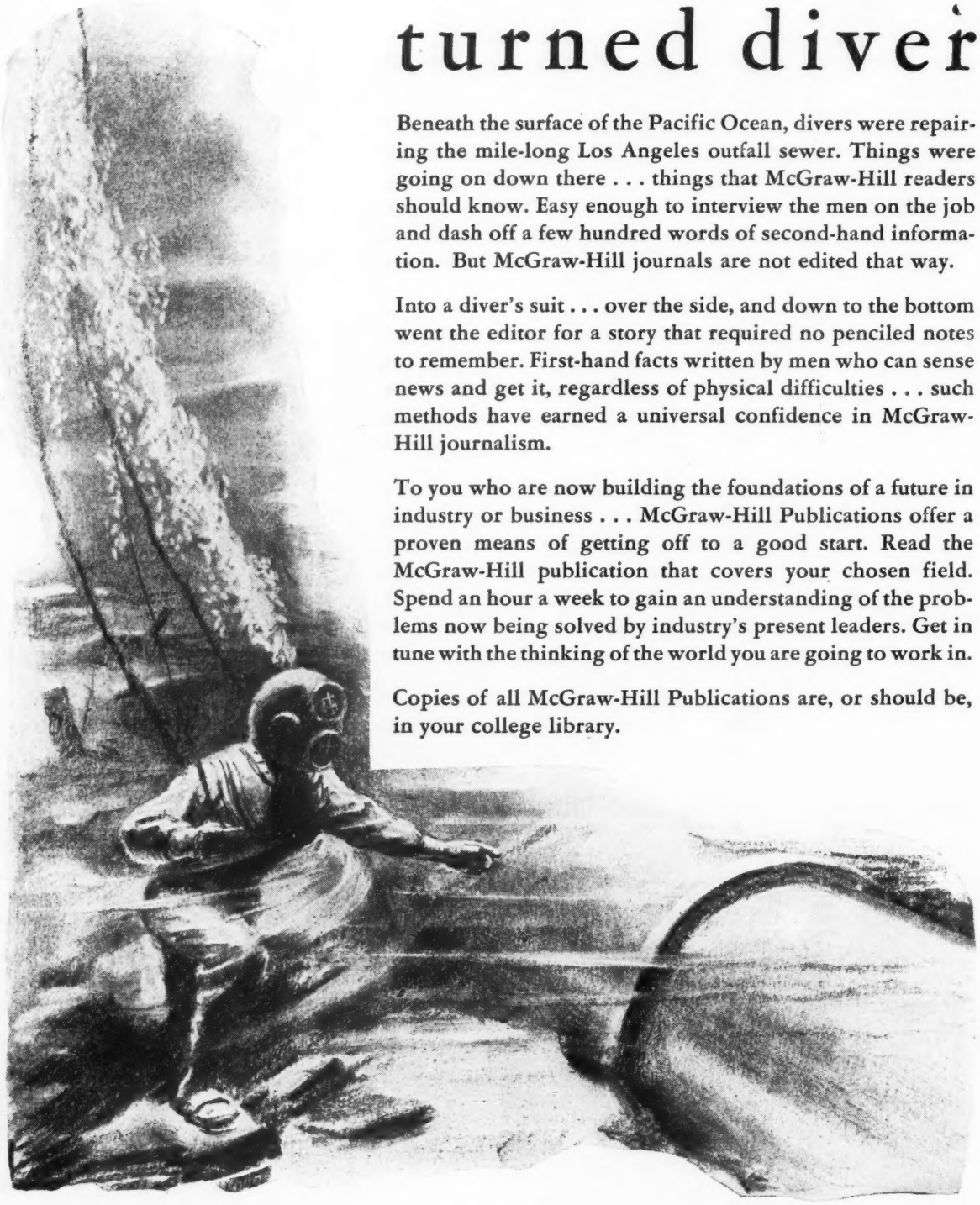

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TABLE OF CONTENTS

	Page
MODERN CONCEPTS OF LIGHT. By Hans Müller	5
THE JAMES MEANS MEMORIAL PRIZE ESSAY. By Alfred B. Berghell '32	6
A GLIMPSE OF THE CERAMICS INDUSTRY. By F. H. Norton '18	8
CONSTRUCTION OF FOUNDATIONS FOR TALL BUILDINGS. By A. Amson	10
THE LAWS OF FATIGUE IN RACING. By Arthur E. Kennelly	12
EDITORIALS	14
THE ENGINEERING FIELD	16
DEPARTMENTAL NOTES	18

Among Our Authors

HANS MÜLLER, author of the article, "Modern Concepts of Light," came to the Institute as a research associate in 1925. He attended the Eidgenössische Technische Hochschule, in Switzerland, from which he received the degree dipl. Ing. in 1923. In 1927, he received his Doctor's degree from that institution. In 1928, he became Assistant Professor at M. I. T.

Professor Müller is interested in the philosophical aspects of science, and in this line teaches, among others, an introduction to physical science. He has worked on the theories of colloids and electrolytes, and at present is engaged in a study of the molecular theory of dielectrics.

ARTHUR EDWIN KENNELLY, Professor of Electrical Engineering at Harvard University and Director of Electrical Engineering research there, is well known among people connected with M. I. T., as he was the chairman of the M. I. T. faculty from 1917 to 1919.

Professor Kenelly received his education at private schools in England and Scotland, and holds honorary degrees from the University of Pittsburgh, Harvard University and the University of Toulouse.

The subject of racing fatigue has interested Professor Kenelly for a long while. His first paper on the subject was presented before the American Academy of Arts and Sciences in 1906. He has revised the data, and presents it in its revised form in this issue.

FREDERICK H. NORTON graduated from M. I. T. in 1918. Following his graduation, he became the Chief Physicist, at Langley Field, for the National Advisory Council for Aeronautics. At the end of four years he returned to the Institute, having received the Babcock-Wilcox Fellowship, as a research assistant. His work consisted mainly in the development of refractories and insulators. The No. 80 fire brick, now widely used, was a result of his investigations in these lines.

He spent two years at the East Liverpool plant of the Babcock-Wilcox Company assisting in putting into production the refractories developed here. This fall, he became Assistant Professor of Ceramics at M. I. T.

MR. ARNE AMSON was born in Farsund, Norway, in 1880, and was graduated from The Technical College of Christiania, Norway, in 1900.

For about five years he was employed by the Norwegian Government as an assistant consulting engineer. He came to the United States in 1906 and soon took a position with The Foundation Company of New York, where he has been one of that company's engineers, specializing in the design and construction of deep foundations. He is now Assistant Chief Engineer of the company.

The character of the rock formation and subsoil of lower New York City requires special knowledge and methods of construction in the foundations of the skyscrapers, and as Mr. Amson has been connected with the work of construction of a very large number of such foundations in New York he has become one of the experts in this line.

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THE PROFESSIONAL JOURNAL OF THE UNDERGRADUATES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

VOLUME XI FEBRUARY, 1930 NUMBER 1

MODERN CONCEPTS OF LIGHT

Recent investigations have led scientists to regard more favorably the corpuscular theory

By HANS MULLER

Assistant Professor of Physics
Massachusetts Institute of Technology

THE investigation and the explanation of the properties of light has been one of the outstanding problems of physics ever since the birth of this science in the seventeenth century. But in spite of the efforts by some of our greatest scientists, Newton, Huyghens, Fresnel, Hertz, H. A. Lorentz, and Einstein a quite satisfactory explanation of the nature of light could not be given. It is only due to the developments of theoretical physics during the last five years that today we believe that we are closer to the final solution than ever before.

At the end of the last century, it was generally assumed that light was an electromagnetic wave, and that all its properties could be derived from the wave solution of Maxwell's equations of electrodynamics. This picture explains almost all our experimental knowledge of light. The interference phenomena verify the wave character and furnish the means to determine the frequency of the light. The theoretical result that the electric and magnetic field are orthogonal to the direction of propagation, or in other words that the waves are transversal, is experimentally shown by the investigations of polarized light. The electromagnetic nature of light is already indicated by the fact that its velocity in free space has the same value as the velocity of propagation of electric and magnetic fields, and the final proof was given by H. Hertz when he was able with help of small oscillators to produce electromagnectic waves which have all the properties of light.

The wonderful developments of experimental and theoretical physics during the last thirty years have furnished an overwhelming evidence that radio waves, heat radiation, infra-red, visible and ultraviolet light, X-rays, and radio active γ-radiation are essentially the same, electromagnetic waves differing only in frequency. The electromagnetic wave theory has been successfully used to explain the dispersion, refraction and scattering of light of all wave lengths. This theory is built up logically on experimentally verified principles of the theory of electricity and magnetism and is able to explain practically all the experimental facts collected during three centuries. In view of this situation we are not surprised that this theory was considered for a long time as a final result. Together with Newton's law of mechanics it formed the fundamentals of classical physics.

But, as classical mechanics presents only approximately the true laws of nature, so also the wave theory explains only one part of the properties of light. The same analytical mind, the same genius, Albert Einstein, who realized the insufficiency of classical mechanics and who was able to give them their new formulation in his theory of Relativity, also was the first to find the weak point of the electromagnetic wave theory. Einstein pointed out the experiment which is inconsistent with this classical theory, namely the photoelectric effect. This effect, first discovered by Hallwachs, consists in the fact that light falling on a metallic plate is able to produce on it a positive electric charge. It is the same phenomena which explains the operation of the photoelectric cell, now so important in the transformation of light into electric current. The investigation of this phenomenon led to the following picture of what takes place: The light is able to throw negative electrons out of the metal, leaving the metal with a surplus of positive charges. This qualitative statement, of course, is consistent with the electromagnetic theory. We should expect that an electromagnetic wave can move electrical charges. However, the quantitative law governing this effect is in contradiction with this theory. According to the theory we should expect that the velocity of the electrons when leaving the metal should increase with the intensity of the light. The experiment, however, shows that the velocity is quite independent of the intensity of light, but is determined by its frequency. Einstein showed that the energy W of the electron is directly proportional to the frequency V of the light, so that one can write $W = hv$. This law, the Einstein-Bohr frequency condition, called after its discoverer and after the scientist Niels Bohr, who showed its importance for all atomistic phenomena, is one of the most important results of modern physics. The first accurate verification of this law was carried out by R. A. Millikan. He found that the factor of proportionality h is identical with the constant introduced by Max Planck in 1900 in his theory of heat radiation, and which is called Planck's constant. The experimental and theoretical research of the last twenty years have shown the universal validity of this law. In all phenomena where the energy of any kind of light is transformed into mechanical energy, the energy gained

(Continued on page 24)

The James Means Memorial Prize Essay

A comparison of the safety of aircraft with older forms of transportation

By Alfred B. Berghell '32

Air versus Sea Travel

At the International Shipping Conference, held in London in June, 1928, the following statement was made:

"In the past fifty-five years British shipping has averaged 4,000,000,000 passenger miles per annum, and 200 passengers have been drowned per annum, or one passenger to every 20,000,000 miles."

That is a remarkable record for safety. Accidents of a serious nature which do happen at sea receive a great deal of publicity, as is the case with aeronautical accidents. Since the war, these have been very few. The modern steamship fitted to carry passengers is surrounded by safeguards, the result of long experience in encountering the dangers of sea travel. Therefore, the safety records of passenger ships are extremely high. During the past eight years not one passenger transported by vessels of the United States Lines has lost a life during the course of a voyage. The most important hazards at sea, fire and fog, have been overcome to a great extent by the use of fireproof materials, fire fighting apparatus to overcome the dangers of fires, and the fathometer, compasses, and the radio with direction finder for the fog.

Let us contrast these records of safety in steamship travel on the seas with those of air vehicles. Before 1927 there were eight attempts to fly the Atlantic, of which four were successful. In three of these four cases the airplanes landed in an undamaged condition at the point intended, and there were no fatal results in the eight cases. In 1927 and 1928 about two-thirds of the attempts to cross the Atlantic have been failures, most of them with fatal terminations. In but a few cases has it been possible to start the flights without long waits upon the weather, and in only three or four cases has the final landing been accomplished without damage to the airplane. No time schedule has been maintained.

These facts would indicate that trans-Atlantic flight by airplane is still a doubtful, unreliable, and dangerous mode of travel, with the dangers growing no less with the passage of time. The fact that land planes have been used in the majority of attempts has added to the danger in case of a descent to the water. Seaplanes are somewhat safer, although at the present time flying boats have not yet reached the state of development necessary for safe trans-Atlantic transportation.*

The other possible means of trans-Atlantic air transportation is the airship. Every flight attempted has been successful, the lighter than air craft terminating its journey at the point previously selected. In one case some damage was done to the ship in flight, but it was repaired as the ship proceeded on its way. The fact that the airship has a number of power plants reduces the hazard from engine failure, which is almost certainly fatal in a single engined airplane. Airships are recognized as being safer forms of transportation by the insurance companies, the "Los Angeles" being insured at a premium of only five per cent when it flew to this country over four years ago. So far, no lives have been lost in trans-Atlantic airship travel, but as only a few flights have been made, it is difficult to make estimates as to the safety which would exist in a regular line. It seems, however, too early as yet to establish such a service, which could not hope to run with the regularity and safety of steamships. The airship can be expected in the future, after additional experience has been gained and technical improvements made, to be used for such a service. The development of the Diesel engine for aircraft use will greatly reduce the danger from fire in hydrogen-filled airships and at the same time increase the reliability of the motive power. The next few years will probably see such an engine made and extensively used. It seems probable that when regular trans-Atlantic service is established by air, the airship, rather than the airplane, will be the means used. So far it has proven itself much the safer and the more reliable.

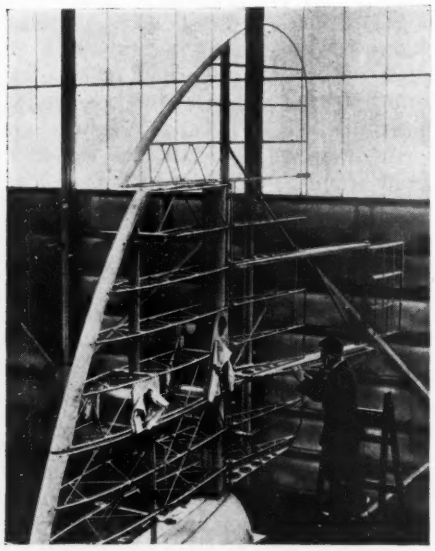
There still remains the possibility of short over-water flights or of coastal airlines. The number of accidents may be expected to be less, because, being within a few miles of shore, storms might be avoided or flights cancelled before starting, in the event of bad weather. In the case of being forced down, help is nearer if radio communication can reach it. But in competition with sea travel, from the safety standpoint, and for year round day by day reliability, sea transportation is still in the lead. Coastal airlines are still young in America, so that figures as to their accidents and fatalities in propor-

The Tech Engineering News takes pleasure in presenting this essay to its readers. The author, Alfred B. Berghell, is enrolled in the course in Aeronautics at M. I. T., and has previously had experience with airplane manufacture.

Mr. Berghell is at present a member of the editorial board of this publication. One of our aims is to develop a higher type of engineering writing, and in this case our efforts seem to have met with success.

INTERIOR
CURTISS "CONDOR" TRANSPORT

Comfort as well as safety is being built into modern airplanes.



FIN AND RUDDER CONSTRUCTION OF THE *CALCUTTA*

The *Calcutta* has been used for air communication between England and India.

*Germany is building large flying boats of from ten to fifty tons, with the intention of establishing a service to South America from Europe. Whether or not even they can be safely operated remains to be seen.

tion to the number of miles flown cannot be secured. One line reports one serious crash and one fatality, due to adverse weather conditions and an exhausted fuel supply, with a consequent forced landing in the water. As a result of this experience they are endeavoring to improve the safety of their equipment. To accomplish this they have added two emergency exits in the cabin and one in the top of the pilot's cockpit. In a compartment in the top of the wing they carry an airaft to be inflated with a carbon dioxide bottle, and passenger chairs are anchored, not only to the floor, but have a cable to the longerons.

Radio equipment and a special radio operator are required. Two pilots are carried, a junior and a senior pilot. Any new pilot entering their service serves three hundred hours as a junior pilot before receiving a ship of his own. Passengers are not carried over routes until ground facilities are highly developed and the whole personnel properly trained. They hope in this manner to make their service as safe and reliable as is humanly possible at the present time.

Organized Air Transport versus Railroad Transportation

During the year 1927, railroads in the United States carried passengers 33,797,754,000 passenger miles and 99 passengers were killed, or one passenger to every 341,391,454 miles, while 5,194 passengers were injured, or one passenger accident to every 6,507,076 miles. Comparing these figures with those resulting from the operation of organized airways in the United States, there was one fatality for every 829,999 miles on the airways, and one accident for every 484,164 miles. These accidents included both pilots and passengers, six pilots being killed, and one passenger. It is evident that for passenger travel the railroads have a considerable margin of safety over the airways. But while the figures given for the airways comprise the total costs in life and accidents for the mileage given, this is not the case with the railroads.

Of persons killed by railroads in 1927, passengers comprised only 1.4 per cent, while employees totaled 23.1 per cent and other persons 75.5 per cent.

The following table shows accidents and fatalities on United States railroads:

Year of 1927, United States Railroads

There were:

341,391,454 passenger miles per passenger fatality
6,507,076 passenger miles per passenger accident
5,841,972 *passenger train* miles per passenger fatality
111,350 *passenger train* miles per passenger accident
657,424 *train miles* (freight and passenger together) per fatality to passenger or railroad employees
12,596 *train miles* (freight and passenger together) per accident to passenger or railroad employees
160,566 *train miles* (freight and passenger) per fatality to *someone*
11,229 *train miles* (freight and passenger) per accident to *someone*

On airways the mileage per fatality and accident is practically the same for passenger and plane mileage, as the average number of persons to a plane is not over 1.3. The mileage per fatality and accident cost is, therefore, about the same. With the railroads there is considerable difference, and when train miles instead of passenger miles are used, the cost in lives and accidents rises considerably. It soars still higher when employees are included, and higher still when fatalities and accidents to everyone killed or injured by railroad operation is included. The cost in lives per mile of operation is high. Part of this high cost is due to grade crossing accidents, a great deal to trespassing on railroad property,

THE AUTOGIRO

Using a new principle, this craft is able to fly safely with little or no forward speed.

CURTISS "CONDOR" TRANSPORT

Growing air traffic and greater operating experience is bringing increased safety to the passenger airplane.

but even when these items are left out the cost is higher than the airway cost.

It may be contended, of course, that airplanes are not hauling the tonnage that the railroads are hauling, and that if they were, their accidents per mile of flight would increase proportionately, but the significant fact in analyzing railroad accidents is that over three-fourths of them are due to the trains striking people who are on the railroad right of way as the trains are operating. That means that if airways can operate as efficiently as railroads, they will still have only one-fourth as many accidents as the railroads, even when they are hauling as large loads and carrying the same number of passengers, for pedestrians or automobilists cannot trespass on the air right of way.

Railroads pay an enormous tribute annually in damages for deaths and injuries which are the direct result of this limitation to ground transportation. There can be but little hope of improvement with the population increasing and the number of automobiles registered in the United States each year growing larger, a certain per cent destined to be turned into junk in railroad crossing accidents. It is obviously impossible to guard every foot of railroad track, and as long as this is the case, non-passengers and non-employees are going to continue to be killed and injured. Terminals can be guarded. Passengers and curiosity seekers do not wander freely around railroad terminal yards. Air terminals can be guarded, and air rights of way cannot be reached except by aircraft.

Air lines should be able to operate much more efficiently in three dimensions, with the total elimination of grade crossings, crossed tracks and curves. Laying out air routes similar to steamer lanes would guard against collisions. With larger planes it will be possible to carry a crew to operate them, instead of only one pilot, as is now the general custom. According to

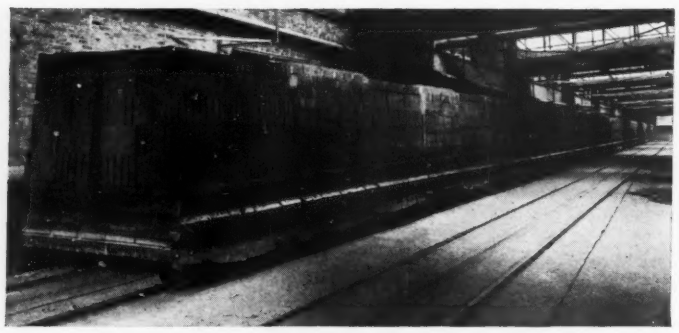
(*Continued on page 30*)

A Glimpse of the Ceramics Industry

M. I. T. is well equipped to train men for work in this important industry

By F. H. Norton '18
Assistant Professor of Ceramics
Massachusetts Institute of Technology

THE subject of ceramics is generally thought of in connection with objects of art such as Chinese porcelains, or a Sévres vase, but in reality it covers the product of a great variety of industries, not only those dealing with clays, but all of the silicate products. All about us we see ceramic articles that are almost indispensable: the glass in the windows, the plaster on the walls, the tile or cement floors, the dishes from which we eat, or the glasses from which we drink. It may perhaps be of interest to go over a list of the principal articles which are included under ceramics to show their great economic importance.



TUNNEL KILN CARS

In this modern plant the bricks are passed continuously through a tunnel kiln where they are burned. Notice that the cars are shielded from the heat.

Abrasives, especially in the form of grinding wheels, have reached a high state of development under the guidance of scientific research. It is well to remember that the manufacture of practically all modern machines, including the automobile, depends upon the grinding wheel, and that our modern mass production would be quite impossible without it. The largest grinding wheel plant in the world is located in Worcester, Mass. Formerly all abrasives were natural products such as emery, sand, etc., but it was found that a greatly superior product could be made in the electric furnace. Two general types of abrasive are now used, silicon carbide and fused alumina. The first is made by combining sand and coke at high temperatures, and the second by fusing bauxite.

All kinds of hydraulic cement come under the heading of ceramics, as well as lime, plaster of paris, and mortars. It is not necessary to point out the great importance of Portland cement in modern engineering construction. Some of the recent developments in cements are the production of quick setting cements of high alumina content. Such cements will have a strength in twenty-four hours comparable with the strength of ordinary Portland cement in a month. The quick setting cement is of great value in repairing pavements where traffic cannot be held up.

Enamels used on iron are ceramic products, and their manufacture is an industry of considerable importance, as the ease of keeping a good vitreous enamel clean is being recognized as of great value in the household. Kitchen and bathroom furnishings are now largely enameled.

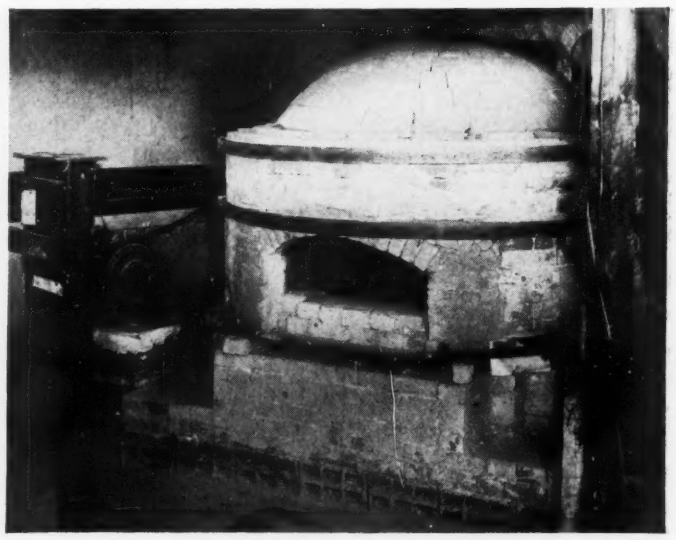
The manufacture of glass is a large industry centered about the deposits of glass sand. A large part of the industry is devoted to the manufacture of plate and window glass, but the use of bottles as containers is gradually increasing and to some extent is displacing the tin can. There are a number of special glasses such as colored glass and optical glass which require the greatest care in manufacture, and a good deal of research effort is expended on these problems. One of the most recent problems is the development of window glass transparent to ultra-violet rays. While a good deal has been done on this problem, the transparency of quartz has not been reached. A large industry has recently grown up for the manufacture of fused quartz utensils.

Heavy clay products such as common brick, face brick, hollow tile, drain tile, and sewer pipes are made in tremendous quantities, but due to their low intrinsic cost are made whenever possible in the locality where they are used. Common brick clays are found everywhere, but clays suitable for the other heavy clay products are not as well distributed, and the center of the industry is in Ohio, Pennsylvania, and West Virginia, where it is frequently possible to obtain the clay and coal in the same mine. Many common bricks are still burned in New England with wood, as it is believed that other fuels cannot give the rich coloring desired in this material. Ware for salt glazing such as sewer pipe requires a more refractory clay, so that coal measure shales are used extensively for this purpose.

Refractories include all ceramic materials capable of withstanding a high temperature. The commonest refractory bricks are made of fire clay, which is fairly widely distributed. The best fire clays are found in Pennsylvania, Ohio, New Jersey, and Missouri; although many other states have excellent deposits. For special service other materials are used: mullite and alumina for higher temperatures, silica for high temperature and load, and chrome and magnesite to resist steel slags.

The largest use for refractories is in steam boiler furnaces and the next largest is the steel industry. A single open hearth furnace or a blast furnace may require one million bricks. Large quantities of refractory cement are used for laying bricks, patching, etc.

Terra cotta is being used to a large extent in many of the modern office buildings, and a number of large plants are making this ware exclusively. Terra cotta may be glazed and colored



CERAMIC KILN

This is a small down-draft, gas-fired kiln for maintaining a uniform temperature. It is a part of the ceramic equipment of the Institute.

to suit the requirements of the building.

The white ware industry which is centered in Ohio and New Jersey supplies mainly white or ivory table ware. There are, however, a few companies in this country that manufacture porcelain ware. Chemical stone ware is also an important industry. The white ware industry is a very old one, and it is most interesting to observe the change that has recently come about due to the necessity of producing goods at a lower cost in order to compete with foreign ware. Some of the smaller potteries are even now using the identical methods that were brought over from England two hundred years ago. Contrast this with the largest and most modern pottery in the world which is located in the East Liverpool, Ohio, district. The dark wooden sheds are replaced by acres of well lighted steel buildings, machinery is used to prepare the clay and form the ware, conveyers handle all material regularly from place to place, tunnel kilns 400 feet long burn the ware in a continuous stream, and even glazing and decorating is partly automatic. This result has only been brought about by scientific research and up-to-date engineering practice.

The importance of the ceramic industry to modern civilization is very great. All buildings use more or less cement brick or tile in their construction, and the modern tendency toward fireproofing will make their use in the future even more extensive. The manufacture of steel is entirely dependent upon refractories, for it would be impossible to obtain the high temperatures necessary in making steel without high grade refractories. Also all modern steam power plants are dependent upon refractories as a lining for their furnaces. In fact, the quality of the refractory oftentimes is a limiting factor in power plant design.

The great importance of glass is obvious, and its use from a scientific standpoint is essential to practically any form of research. Ceramic products have always ranked high in the field of art, and although this country does not turn out as many individual pieces of distinction as many foreign countries, on account of the cost of labor and the use of mass production, there are a few plants and studios turning out ware of the highest grade.

It is rather difficult to estimate exactly the value of the ceramic products made each year in the United States, but the ceramic industry is undoubtedly among the ten largest industries, with an annual value of around one and one-half billion dollars.

Graduate work in ceramics has recently been started at the Institute as a part of the Department of Physics

Courtesy *Babcock and Wilcox Co.*

CATENARY ARCH

The theory of this new type of high temperature furnace arch was worked out here in the Physics Department. This form has been found much superior to the usual circular type.

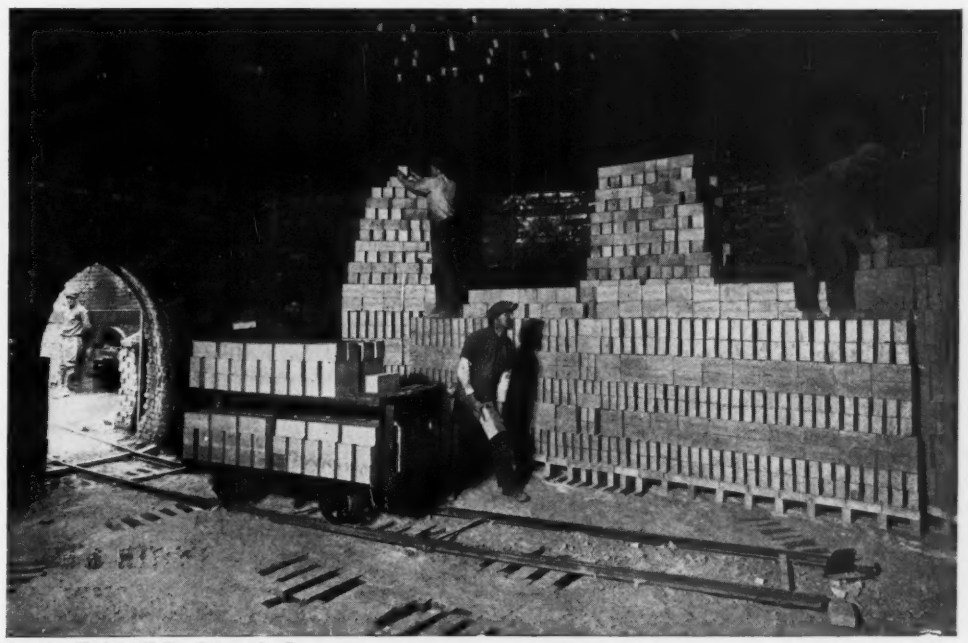
because it was known that such a large and important industry was in need of men having a fundamental training in the subject. As will be evident from the preceding paragraphs this subject is a very broad one, and it would, of course, be impossible to equip a man to handle the details of all the branches. It is hoped, however, that we will be able to train the student in the fundamentals of the essential physical and chemical processes involved, so that he will have a clear insight into any problems that come up. There is a large and continual demand for men with more than the usual undergraduate training in ceramics; that is, men are wanted not so much with the trade-school type of education, but with a training in the fundamentals of physics and chemistry applied to this art.

We have at the Institute a small but well-equipped Ceramics Laboratory for taking care of all the usual commercial processes on a small scale. We are especially well equipped with small furnaces and temperature measuring devices for carrying on precise work. It is intended to have special lecturers take up various branches of this subject during the year as it would be impossible for any one man to be thoroughly acquainted with all branches of this subject.

In the past the Department of Physics has done considerable research in ceramics, especially in the field of refractories. The present head of the department was interested some years ago in the development of Portland cement concrete as a material for use in the construction of fireproof buildings. Later he was largely interested in the development of the manufacture of asbestos boards, and shingles, and the little press built in 1906 for the manufacture of the first piece of asbestos wood is still used for instruction in the Heat Measurements Laboratory. In the last ten years with Professor Wilkes he has been carrying on development work in refractories, and most of the silica bricks in this country are now made by the process developed in the department. Development work which has been going on in the department for a long time in connection with a number of other workers has resulted in the production of a refractory for high duty use. A large plant is now being constructed in the South to make this type of brick in larger volumes than at present.

Considerable work has also been done in developing an insulator that will withstand high temperatures. Some very interesting furnaces have been constructed with this refractory insula-

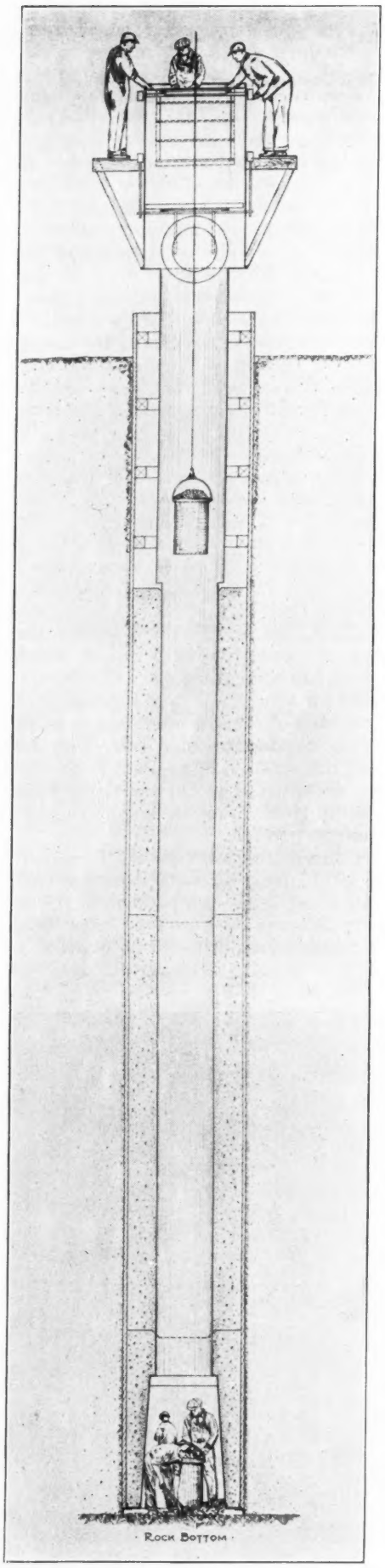
(*Continued on page 20*)



Courtesy *Harbson-Walker Refractories Co.*

INTERIOR OF A FIREBRICK KILN

This illustration shows the method of setting a round down-draft kiln preparatory to firing.



PNEUMATIC CAISSON FOUNDATION

Construction of Foundations for Tall Buildings

The extreme height of our modern skyscrapers complicates the problem of adequate foundations

By A. Amson
Assistant Chief Engineer
The Foundation Company

IN the congested portions of the larger cities where the great heights of the buildings concentrate enormous loads on the columns, many difficult problems are encountered in the construction of foundations.

The height of the buildings is so great that the slightest irregularity of settlement in the foundations would produce a greatly magnified variation from the vertical in the superstructure and would cause great injury and destruction to elevators and machinery. It is, therefore, necessary that the foundations must be absolutely immovable, or that, if displacement occurs, it must be perfectly uniform.

Where the rock is near the surface and above water level, as in some portions of New York City, no difficulty is involved in securing a good foundation. Where, however, the site is on filled land, or when it is on quicksand or other soft material, great difficulty and expense may be involved in providing stable supports for the building and in preventing settlement of the adjacent buildings and streets.

Foundations on soft soil are of three types: 1. Those spread over the surface; 2. Those supported on piles; and 3. Those carried to rock or other hard stratum.

Examples of all three types are found in New York, where in certain areas the conditions of the soil are bad and the buildings are taller than in any other city.

Spread foundations have been used in New York City in a few cases, where the possibility of undermining by adjoining building operations is remote. The spread foundation consists generally of a continuous reinforced concrete mat covering the entire building area, and sometimes this mat is surrounded by a steel sheeting cut-off wall as an additional safety against undermining.

This type of foundation has, of course, its limits. The sand in New York is as a rule not good for more than about 3 tons per square foot, which will limit the spread mat foundation to not more than 20-story buildings, and where rock can be reached without too great an expenditure of money, it is a poor policy not to secure absolute stability by carrying the foundations to rock.

Piles, both timber and concrete, have been used in New York for buildings up to 30 stories or more, but even this type of foundation should not be resorted to if rock is within a reasonable reach. Timber piles have also the disadvantage that, unless they are cut off at a considerable distance below ground-water level, there is danger of decay of the tops, as the ground-water level may be permanently lowered by adjoining subway or deep cellar excavations. Several examples of this condition have occurred in New York in the last 10 years, and the owners have been forced at great expense to underpin their buildings and remove the decayed tops of the piles.

Another type of pile, that has been used extensively in New York in the later years for buildings up to 35 stories high, is the steel pipe pile. These vary in diameter from 10 to 18 inches and usually have a thickness of steel shell of $\frac{3}{8}$ inch. The pipes are driven to rock, cleaned out with an air jet and filled with concrete. On a pile of this type New York City building code permits a load of 500 pounds per square inch on the concrete and 7,500 pounds per square inch of the steel shell, deducting $\frac{1}{16}$ inch thickness for possible corrosion, no pile to be longer than 40 times the inside diameter, and not more than one splice permitted in the length of the pile.

Several piles of this type, that have been in the ground 20 to 25 years, have later been exposed by subsequent foundation operations, and have been found in excellent condition in regard to the effects of corrosion on the steel shell, but many signs have been found showing the effects of overdriving the pipe, as indicated by longitudinal cracks, bottom of the pipes being split over a boulder, or the bottom caved in by hitting a boulder on the side.

In New York City where the rock is overlaid by a layer of hardpan, in some cases as much as 20 feet thick, the uncertainty of actually being able to reach the rock with this type of pile should exclude them as a foundation for a permanent heavy building. The writer knows of at least one case where during the sinking of a pier to rock, the adjoining building, supported on pipe piles supposedly resting on rock, settled during the sinking operation, and it was found that the pipe piles actually

were resting in the hardpan, one to two feet above the rock.

For such tall buildings as are being built in New York today, ranging in height from 30 up to 70 stories or more, the only safe and stable foundation is concrete piers supported on rock, and the method used in constructing these piers has, in the downtown part of the city, as a rule been the pneumatic caisson method. Piers to rock have in some cases been constructed by the open method with use of steel sheeting. In these cases the steel sheeting is driven from the general excavation level down to and as far into the hardpan as possible, the water is pumped out and the pier excavated in the open. The hardpan generally is very dense and practically water-tight, so in many cases it can be excavated without any protection of the banks. Occasionally, however, pockets and seams of quicksand or sand and gravel are found, and in such cases it may be necessary to convert the steel sheeted box to a pneumatic caisson by constructing a deck in the box and do the remainder of the excavation under compressed air.

The depth of the rock south of City Hall in New York varies from 30 to 100 feet below the surface. On top of the rock there is generally a layer of hardpan varying in thickness from 1 to 20 feet and above this is very fine sand or quicksand. Groundwater is found anywhere from 10 to 30 feet below the surface. Under soil conditions like this, the steel sheeted method as mentioned above is limited to the shallower depths and where heavy buildings are adjoining the property, the risks involved in loosing ground are often great enough to justify the use of the more expensive pneumatic method.

These tall buildings require as a rule considerable space for their permanent machinery, vaults and storage space, which cannot easily be spared either from the ground floor or basement under the street floor, so that not only have sub-basements been put in, but also cellars and sub-cellars under them, making from two to five floors below the street level.

As a typical example of this type of construction can be mentioned the 31-story New York Telephone Company's Building, which occupies the entire city block between West Street, Washington, Vesey and Barclay Streets.

Unusual conditions found at the site made the construction of the foundations for this building difficult. The preliminary borings developed that, as the site was located outside the original shore line of the Hudson River and was on filled land, timber cribwork and filling material of almost every character would be encountered between the surface and bedrock, which lay from 55 to 75 feet below high water level. Ground water was found from 2 to 4 feet below curb.

The water being so near the surface permitted very little excavation, before the outside watertight cofferdam wall was constructed, in fact all that could be done was to clean out the old walls and footings to give room for the construction plant required for constructing the cofferdam wall.

This cofferdam wall was formed by a series of pneumatic caissons sunk end to end, with joints between filled with concrete under air after the caissons had reached rock.

The 22 caissons were built of reinforced concrete, they were 8 feet wide and about 40 feet long. The intervals between them were about 18 inches wide, and the concrete joints filling the intervals were keyed into the caissons. The caissons at the corners of the lot were beveled at the ends to conform to the shape of the site, which was not rectangular. The depth to which the caissons were sunk varied from a minimum of 55 feet to a maximum of 75 feet. In the process of sinking the caissons, fill, silt, stone-filled cribs, boulders, peat and quicksand were successively encountered. The average actual sinking time for a caisson was about 20 days, although the maximum ran as high as 36 days for one caisson which was sunk through about 20feet of stone-filled crib.

THE SINKING OF A CAISSON

Realizing that the blocks are made of cast iron, the reader will get some idea of the weight sometimes necessary to sink a caisson.

Two inch tongued and grooved plank was used as an outside form for the concrete caissons, and this form was left on and sunk with the caisson. This may seem to be a waste of material, but removable forms require considerable storage space, and on a job of this type every square foot on the lot is valuable; the timber surface reduces also the friction in sinking, which is very important, as it is not unusual to place as much as 800 to 1,000 tons weight on top of a caisson in order to sink it to its final position.

As weights, cast iron blocks weighing one and two tons apiece were used. These were handled very easily by the derrick booms. After a caisson had been sunk to the rock, and all soft rock removed, it was ready for the filling of the working chamber. This was done by dumping the concrete through the air lock. One cubic yard at a time was locked in, the lower door opened, and the concrete dropped to the bottom. This operation continued until the concrete rose about 10 feet up the shaft, when vent pipes, which were placed in the ends of the working chamber, were opened until the grout rose to the top of the caisson. Air was taken off about 12 hours after the concrete was placed in the working chamber.

The excavated material was hoisted from the caissons in buckets and dumped in storage hoppers, which discharged directly into trucks on the streets.

When two adjoining caissons were sunk and sealed, the joint between them could be completed. To accomplish this the dirt between the ends of the caissons was excavated down to 4 or 5 feet below the tops of the caissons. A piece of steel shafting was then concreted in between the caissons and an air lock bolted to the top of this shafting. Air was then turned on and a man sent down to continue the excavation.

As the excavation proceeded the man in the bottom boarded up the space between the caissons on both sides of the joint by nailing planks to the nailing pieces left in the ends of the caissons, and as soon as about 4 feet were

(*Continued on page 36*)

The Laws of Fatigue in Racing

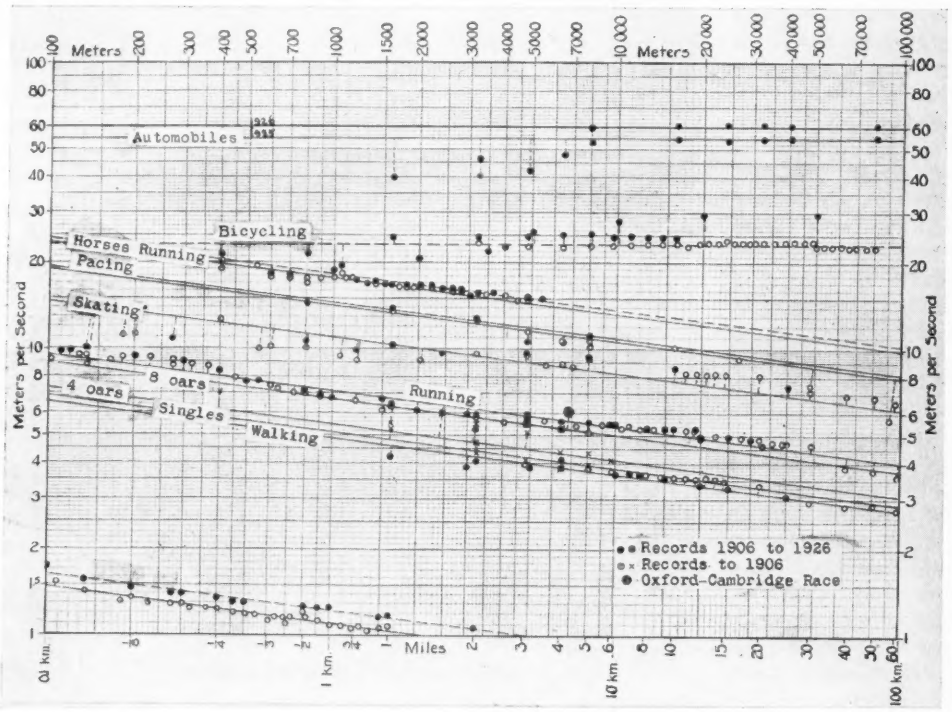
A graphical analysis of racing records yields interesting information concerning the capacity of men for physical exertion

By ARTHUR E. KENNELLY
Professor of Electrical Engineering
Harvard University

RACING between men, either on foot or on horseback or in chariots, goes back to the beginning of recorded history. Ancient Greece and ancient Rome brought such racing contests to a high state of development; but owing to the lack of chronometers or instruments for the precise measurement of time, they had no means of passing on to us accurate information concerning the speeds of the runners. We can never hope to know how the racing records of the modern Olympian contests compare with the famous athletic performances in the old Greek Olympiads. We know only some of the infantry achievements of the ancient world in long forced marches occupying a number of days.

During the last hundred years, however, much quantitative information has been accumulated and recorded concerning the times occupied by racing men and racing horses over a long series of level course distances. Athletic literature has offered, for many years past, a steadily lengthening list of record times for various distances in the following types of contest: Men: Swimming, walking, rowing (singles, 4-oars and 8-oars), running, skating, bicycling and automobiling (nine modes of progression). Horses: Trotting, pacing and running (three modes of progression).

All of this valuable information is readily accessible to the public. For example, the *World Almanac* of New York contains such lists of world's racing records. A list of world's records in one of these series of events sets forth the successive distances and the observed times in which they are run, starting from rest. Denoting the distance of any one event by L and the record time by T, we are able to derive the average velocity V of the runner over the course. Everyone knows that the short races are run at higher average speeds than long races, but there are certain underlying statistical laws or approximate numerical relations governing all these events that can readily be revealed on more careful examination. In order to bring all the data into the simplest form, especially for international comparisons, it is advantageous to reduce all the record times to seconds, and all the record distances to meters, or world-yards, remembering that a meter is very nearly 10 per cent longer than a yard; so that 100 meters may be taken as 110 yards. We then proceed to plot the events graphically upon logarithm paper.



RECORDS OF ELEVEN MODES OF RACING

All the graphs of men's and horses' racing have the same slope, indicating that both men and horses obey the same laws of fatigue. The straight lines of automobiles and bicycles indicate a lack of fatigue.

Log paper has the valuable property that points plotted upon it as ordinates, corresponding to uniform powers of numbers marked off as abscissae, fall upon a straight line. Thus if we mark off along the horizontal base the numbers marked, say 1, 2, 3, etc., and correspondingly mark off on their successive ordinates, the squares of these numbers (1, 4, 9, etc.), the points so marked will lie on a straight line. The same would be true if we plotted cubes or higher powers, and likewise if we plotted fractional powers, such as square roots. Moreover, if when we plot successive pairs of numbers on log paper, the first member of each pair vertically as ordinates, the second member horizontally, as abscissae, we find that the plotted points lie on a straight line, we may surely infer that the first members are all the same power of their mates in each pair. The size of the power is revealed also by the slope of the straight line drawn through the points. Furnished with some sheets of log paper, we may plot any series of world's records, excepting bicycling and automobiling. There are three quantities to select from; namely, the course length L meters, the record time T seconds, and the average velocity V in meters per second over the course. Any one of these three, say T, can be plotted against either of the other two. There are thus six different plots that can be made, either on six separate sheets or to different scales on one and the same sheet. In the latter case, of course, the plots will cross and perhaps confuse each other; so that it is better to commence with one plot only on each sheet of log paper. It will then be found that *each plot is approximately a straight line.* This means that in any series of world records, say those of running horses, the length L is at least approximately a certain power of the time T, and also another power of the velocity V; while corresponding statements can be made for T with relation to L and V; or for V with relation to T and L. These statistical relations, within the degree of precision that the observations war-

rant, and within the limits of distance, time, and average speed covered by the series, may be said to constitute the laws of "fatigue" of running horses in world's record races.

The world's series of running-horse records cover ranges of from about 600 meters to 6,500 meters in course lengths L, from about 34 seconds to 430 seconds in racing times T, and from about 20 meters per second to 15 meters per second in speeds V.

An examination of the slopes of the straight lines in the various plots on log paper, as between the three variables L, T and V for running horses between these limits, we find that:

(1) Times T approximately follow the 9/8th power of the distances L.

(2) Times T approximately follow the inverse 9th power of the speeds V.

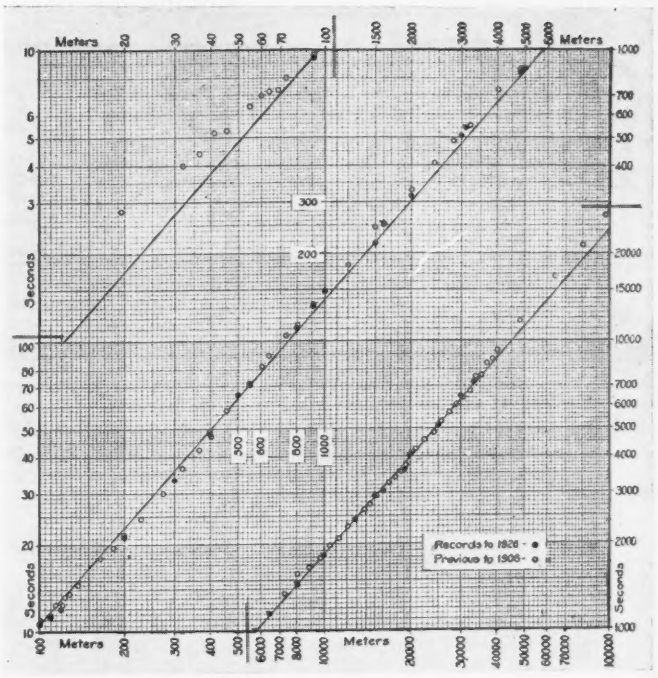
(3) Distances L approximately follow the 8/9th power of the times T.

(4) Distances L approximately follow the inverse 8th power of the speeds V.

(5) Velocities V approximately follow the inverse 1/8th power of the distances L.

(6) Velocities V approximately follow the inverse 1/9th power of the times T.

If we now turn to some other series of world records, say those of swimming men, and plot these similarly on the same sheets of log paper, we shall find that the points fall on other straight lines, which, however, lie parallel to those of the running horses. The same would be found true for all of the series of world records that have been mentioned, excluding bicycling and automobiling men. We are thus led to the remarkable result that *within the degree of precision that such statistical records present, the laws of racing fatigue are the same, or at least substantially the same for horses as for men, with horses in any of three gaits, and with men in any of five gaits.*



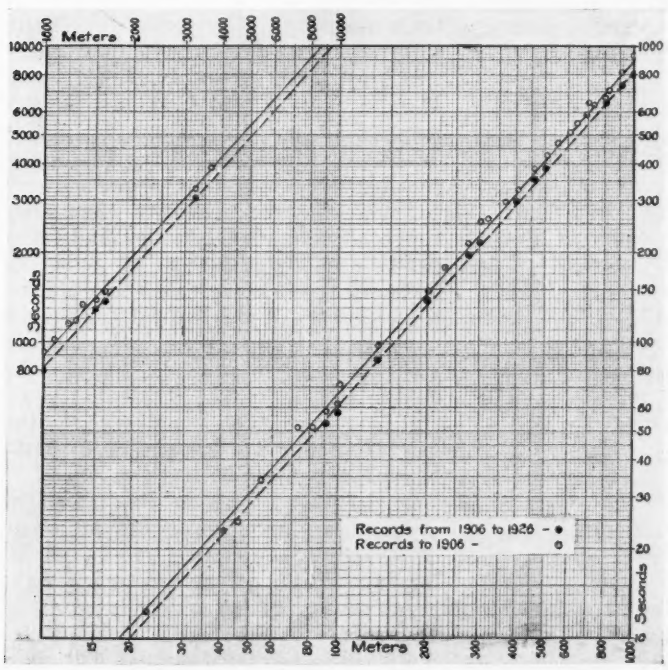
WORLD'S RUNNING RECORD

A study of this graph as suggested in the text will reveal the chances of a world's record being broken.

Deductions from the Observed Statistical Laws of Fatigue

If we take law (1), we find that it means doubled distances require about 118 per cent more time: while increasing the distance 60-fold means increasing the time 100-fold. The distances rarely cover a range of sixty to one; but a number of events cover a doubled distance. The mean observed time increase for 146 cases of doubled distances is 2.173 as against 2.181, the theoretical value for the 9/8th power.

Considering law (2), it means that if the velocity over the course is halved, the running time is increased 2^9 times or 512 times. Taking the record speed of 9.615 meters per second in the 100-meter dash, for which $T = 10.4$ seconds, then reducing the speed to $V = 4.808$ meters per second, or one half, should increase the racing time to $512 \times 10.4 = 5{,}325$ seconds. The nearest record time to this is 5,286 seconds for the run of 16 miles or 25,750 meters, with a mean velocity V of 4.872 meters per second, not far from the 4.808 expected.



WORLD'S SWIMMING RECORDS

These records follow most closely the theoretical laws of fatigue, as compiled by Professor Kennelly.

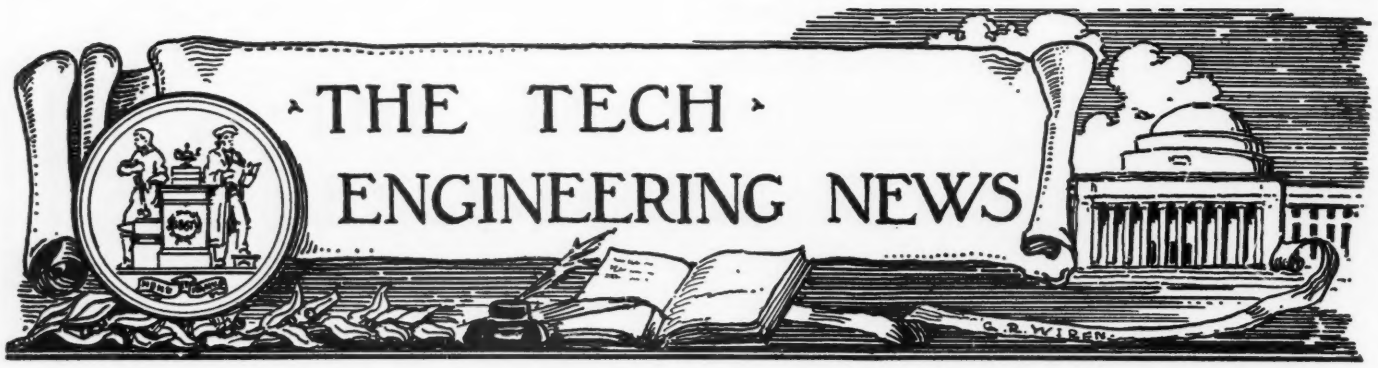
This example shows how sensitive is the relation in world-record events between the runner's speed V and the time he can maintain this average speed before becoming exhausted. If his speed is raised one per cent, his running time is reduced nine per cent. The speeds of rowing, running, skating, walking and swimming are naturally quite different; yet the racing time in each and all is substantially as the inverse ninth power of the speed.

Laws (1) to (6), as stated above, are so interrelated that from any two of them all the four remaining may be inferred. It is therefore unnecessary to examine all of them. Law No. (4) is an interesting mode of presenting the facts. This states that the running distance L varies inversely as the eighth power of the speed, in any one series of world-record racing events. This means that if the average speed is doubled or halved the running distance available is reduced 256 or increased 256 times. In the same way an increase of speed V of 20 per cent reduces the running distance 4.3 times, and increasing the speed 50 per cent reduces it 25.6 times. Consequently, if the speed over a course of 1,000 meters is approximately 7.17 meters per second, then over a course of 25,600 meters it should be one third less, or 4.78. The actual record already mentioned for the 25,750-meter course was 5,286 seconds or 4.872 meters per second.

Practical Deductions from the Records and their Underlying Laws

Thus far we have considered only the actual statistics of the world's speed records and the laws directly deducible therefrom. There is no escape from these laws within the range of each series of events and within the limits of deviation found in the plotted straight lines. We now come, however,

(*Continued on page 22*)



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Editorials

PRESENTING VOLUME XI

WITH this issue, the newly-elected Managing Board takes over the guidance of THE TECH ENGINEERING NEWS. We realize that past boards have set a high standard for us to maintain. This publication stands alone in the engineering and scientific world, for nowhere else can one obtain in an authoritative, non-popular way a broad view of the world of science.

When compared with other college engineering publications, we are somewhat handicapped. Student news is adequately cared for by *The Tech;* alumni find that the *Technology Review* fills their own peculiar interests. We therefore are obliged to omit two large sections contributing to the success of a college publication. In order to have a reason for existing, we must be the best possible kind of an engineering journal. To that end we shall bend our efforts.

One of the most gratifying phases of our work is the interest of our readers. This is not a passive, but an active interest. Daily we receive comments on our work, favorable and unfavorable. These are most helpful; we shall always welcome whatever comments, suggestions, or criticisms our readers may offer.

To the undergraduates, especially Freshmen and Sophomores, we should like to take this opportunity again to invite them to take a hand in the work of running a publication. On THE TECH ENGINEERING NEWS, there is always work and a chance of success for interested students. We believe that a decision to come out for THE TECH ENGINEERING NEWS will never be regretted. The work is pleasant, contacts are many, and of all activities, is the one which will be the most useful after graduation.

GRADES

THE first term's battle is over and we have had a chance to count the losses. Some of us have been victorious and others have met defeat. And again we resurrect the time-honored balm for the conscience — "Grades don't mean a thing."

This is a question that is always debatable, and there are probably as many opinions on the subject as there are people offering them. Many instances can be cited of poor grades and subsequent success, and vice versa. It is probably true that the greater number of seriously thinking people agree that good grades are an indication of a future success.

What do grades show? Obviously they can give very little estimate of a person's native abilities. A person of ordinary intelligence can drive himself to get grades of the highest type while a brilliant student can let his work slide. Grades do indicate the acquired characteristics of the student. Good standing indicates perseverance and attention to work, an ability to make the most of what he has.

It is, then, wise to bank on the student with good grades. The chances of drawing a winning card are far larger. While a person may have great ability, if he never has used it, he probably never will. A good student will have qualities that will make him useful in some capacity, even though he may not attain prominence in his work.

LET'S LEAVE HIGH SCHOOL

A COURSE of study in a high school is a somewhat disjointed thing. One subject has little, if anything, to do with another. When a student changes classes, he leaves one world to enter one absolutely different.

The high school cannot be blamed for this, of course. The subject matter it has to teach is of such a nature that its parts cannot become interwoven to any great degree. Furthermore, the principal aim of the high school is to prepare its students for a higher education.

The one danger in this situation is that the student has acquired the habit of regarding one subject as distinct from another. While this habit may not be fatal, it deadens the creative ability of the student; it keeps him in the realm of the laboratory drudge, the draftsman, or the small business man. When one reaches an institution of higher learning, the essential unity of knowledge ought to impress him. He must realize that a broad viewpoint is necessary to success; he must learn to see the basic connection of one thing with another.

Consider, for example, the experience of a Freshman at M. I. T. He finds it necessary to study among others mechanics and calculus. Now, the calculus is used extensively in mechanics, and no one could fail to note the connection between the two. The point is, that most students take the use of calculus in physics as granted, and fail to appreciate that the calculus is a mighty tool, potent in attacking problems in mechanics. Without the calculus, physicists would have been seriously hampered in their work — mechanics would never have been so completely understood as it is now. The successful student will always regard the calculus as a tool, and attempt to devise new ways to use it. The unsuccessful student will take calculus in mechanics as granted.

A CALL TO RESEARCH

"RESEARCH" is a word that one often sees on many of the doors that line the corridors of the Institute. But one sometimes wonders how much of this research is really applied science as distinguished from pure research. Not only at Technology, but in other schools and institutions devoted to scientific work throughout the country, the emphasis has been and is still being placed on the application of the fundamental principles of nature that were set forth during the last few centuries, rather than on original investigation in the field of the science itself.

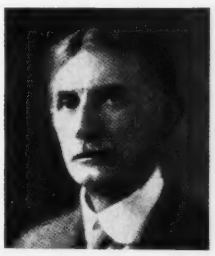
The question put to every worker in the sciences as well as in many other fields is, "How much money is it worth?" If a scientist has to answer that he does not see any practical use for it at present or in the future, the world at large takes little interest in his work or his pay. Then, usually, because he and his family must eat, he devotes his time to making money now instead of laying the foundation for the happiness and wealth of future mankind.

The old saying, "You cannot stand still, you must either go forward or backward," is as applicable to the whole world as to a country or person. Our great and prosperous country cannot continue its greatness and prosperity without seeing that as the structure uses, the foundations are sunk deeper and deeper into the laws of nature.

It is in the field of pure research that the great discoveries of today and tomorrow are to be made. In the seventeenth century there were many new lands to be discovered and the adventurous and courageous youth went out to the territorial borderline that separated the known from the unknown. In the next two centuries there was still more work of exploration and discovery to be done. Now, in the twentieth century, there is a strong call to the adventurous and intelligent youth in the field of pure research. It is there that men are working in a mysterious scientific borderland. There, men find the pride and joy of bringing a truth out of the unknown and thus further and further extending the boundary of human knowledge.

The love of truth and the supreme joy of discovery are the life blood of the scientist who devotes his life to pure research. Money must be a secondary matter to men in this calling who count their happiness not by the amount of the bank balance, but by a much finer, nobler, and what we believe to be a much truer standard.

PROFESSOR ROSS F. TUCKER



Prof. Ross F. Tucker, Head of the Department of Building Construction, is a native of California, being the son of one of the pioneer miners of the state. He received his primary education at the Oakland High School, after which he went to the University of California for two years. Following this he enrolled at M. I. T., from which he graduated in 1892 with a degree in Architecture.

While in the West and during vacations he had been working with Ransome, the inventor of almost all the uses to which Portland cement has been put. Upon graduation he prepared the technical data and lectured in cities throughout the United States for architects, engineers, and builders on the uses of the then little known reinforced concrete. This work was the beginning of the future tremendous development of reinforced concrete in the United States.

He is the deviser of several methods of handling concrete which are in universal use today. When the New York subway builders were searching for suitable sidewalk-vault lighting systems to admit daylight from the streets above without interfering with traffic, he developed the method which after exhaustive tests was found to be vastly superior to all others and was adopted not only for the subways but for many other important buildings, so that it is now almost universal.

Another one of his developments is the fireproof concrete floor made with a base of steam cinder concrete. At the time of its introduction in 1898 all fireproof floors in New York were built of terra cotta; now they are all built of concrete substantially along the lines which he devised thirty years ago. This same period saw the introduction of the solid two-inch partition, another device which he helped to perfect and which is now in widespread use. He also conducted many of the first fire tests for the city.

Following this came the development of welded metal wire fabric, much less expensive than the older expanded metal which was used before. His adaptation of it to the use of concrete has now become standard practice.

In introducing all of his devices and methods he had a continual struggle with authorities, building codes, competition and trades unions, all of whom opposed them at first but later saw their advantages. All this time he was actively engaged in actual building operations.

When the Great War broke out he went to Camp Upton where he joined the staff of the Thompson-Starrett Company to build a cantonment for the 77th Division. He supervised the erection of all of the technical buildings, installed the water works with a capacity of 4,000,000 gallons daily, drilled the wells, brought the pipe lines three miles across country, and built the storage and distribution systems all in sixty days. Following this he built the largest laundry in the world with its own power plant, installed thirty-eight carloads of machinery and had the plant running, also, in sixty days.

He also built the Quartermaster's Stores at Port Newark, and then at Nitro, West Virginia, in eight months built a water and sewage system large enough to supply the city of Baltimore.

Following the war he remained with the Thompson-Starrett Company until 1926, when President Stratton requested him to come to M. I. T. and organize Course XVII in Building Construction. He was given complete charge and had to pioneer the manner of teaching it as there was no precedent to follow. The thoroughness of his method is attested by the fact that the first graduating class is doing excellently, one member already being acting superintendent on a large building operation.

THE COVER

OUR cover picture this month depicts a scene on the Wengernalp Railway, Switzerland.

The Engineering Field

Abstracts from the leading professional and trade journals

An Aero Fire Extinguisher, closely resembling a regulation pistol, and operated in the same manner, has been introduced by an Ohio manufacturer. The new device, which is intended primarily for use on board airplanes, contains one quart of an aero fire extinguishing fluid, and is capable of ejecting a stream 35 feet in length.

The extinguisher as used on aircraft is mounted inside the fuselage in a jar-proof bracket within easy reach of the pilot. When fire occurs, he reaches forward, grasps the butt, and pulls the trigger. A stream of fluid containing carbon tetrachloride is then directed to the carburetor, the draft stream in front of the motor, and to the manifold. The fluid expands 3600 times upon contact with heat and effectively smothers the flame. If fire occurs in other parts of the craft the extinguisher can be removed from the bracket and the fluid directed at the flaming part using the trigger as the control.

As an additional safeguard, the extinguishing fluid is a non-conductor of electricity, thus obviating any danger from short circuits in the ignition lines. By the use of this device, a pilot may control fire in a plane, and still have one hand free for navigation of the ship, thus enabling him to land safely.

Courtesy *Power Plant Engineering*

UNIT HEATER INSTALLATION

Unit heaters suspended from the ceiling of this factory provide an even distribution of heat.

A Giant Blast of 45 Tons of Dynamite was set off in the construction of a western hydro-electric dam. Providing enough energy to instantly demolish two city blocks of ten-story granite buildings, this blast freed a quarter of a million cubic yards of material to be used in the construction of the dam.

Forty-one six-inch holes spread over a distance of a thousand feet and 80 toe holes were drilled previous to the blast, and charged with explosive to a depth of almost 160 feet. Cordeau, an explosive fuse, was used as the detonating agent, and was run the entire length of each hole before charging. Electrically fired primers used at each toe hole and along the length of main holes were connected through a knife switch to the main lines. When the blast was fired, three separate explosions were noticed, two from the explosive fuse, and the third from the main charge.

Unit Heaters for factories, showing great superiority in efficiency and ease of installation and maintainance, have been used to replace the old type of cast iron radiators. The heat is evenly distributed by an electric fan blowing an air current over brass or copper coils which are usually equipped with fins to increase the heating surface. The heater may be placed wherever needed since it has an enormous radiating surface for its small size and weight, due to the air draft, and the material of which it is built. The illustration shows several unit heaters suspended from the ceiling in a factory. Heat is distributed more evenly and the temperature can be better regulated than with the old type radiator.

Spherical Containers for transporting gas under high pressure have been developed in the transportation of helium, using a special type of railway car to carry them. These containers are capable of transporting helium at a pressure of 2,000 pounds per square inch, so that the car, with a capacity of six spheres, can carry 210,000 cubic feet of free helium.

The spherical container has the advantage of being 25 per cent lighter than a cylindrical container of the same capacity, besides being simpler in design and construction and requiring the least material to envelop a given volume.

The sphere is made of two plates 1½ inch thick, each formed into the shape of a hemisphere, the two hemispheres being electrically welded together. The outside circumference of a test sphere was 237.5 inches at the weld, and 237 inches at right angles to it. The thickness of the wall of the vessel at its minimum was 1.5 inches and at its maximum 1.9 inches, the increase in the thickness over the original plate being caused by forming the hemispheres from the flat plates. The steel used in construction was of 0.20–0.30 per cent carbon content, having a minimum ultimate strength of 55,000 pounds per square inch and a minimum yield point of half this value. Although the vessel weighed 8300 pounds, it was very true in shape, and could be easily rolled along a flat surface. After fabrication the sphere was heated for a period of four hours in an automatically controlled furnace at a temperature of 1200 degrees Fahrenheit in order to remove internal stresses.

Before being put into use on the railways, the spheres were subjected to rigid tests. To reproduce the conditions of a train wreck, a car carrying a sphere between two cylinders was pushed off a trestle 25 feet high at a speed of 20 miles per hour. The sphere showed some marks where it had hit some rocks, but remained whole. It was filled with air at 1200 pounds per square inch pressure during this test.

During a vibration-fatigue test a sphere was subject to 20,000,000 blows by four air hammers while revolving on a turntable. During this test the sphere was under a hydrostatic pressure of 1250 pounds per square inch. The test running for 75 consecutive hours showed that the sphere was able to stand up under fatigue and vibration which would not be equalled under years of actual traffic conditions.

A Miniature Car weighing 600 pounds and having a 60-inch wheel base is to appear on the United States market. The car is of the coupe type, powered by a four-cylinder air-cooled motor. A notable feature is that the car has no springs or chassis. The wheels are supported by rubber shock cord and the mechanism is connected directly to the body. The rear end contains four universal joints — one on each side of the differential and one in each wheel — thus doing away with an axle housing.

The small vehicle can hold to the

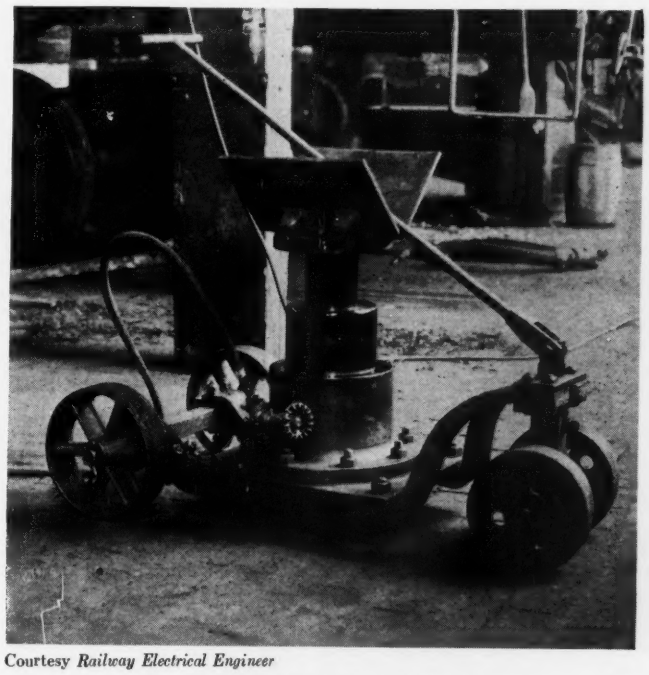
road at 60 miles an hour and rides as comfortably as many heavier cars. It is to be provided with an electric starter, gasoline tank under the cowl, standard gear shift, and a two-seater body with ample leg room. The garage is included in the purchase price, coming in the form of a waterproof packing case.

Radio Photos were transmitted to airplanes from the ground in a series of tests carried on by a German air line. Using the apparatus commonly found in stationary receivers, very satisfactory results were obtained, so the company is contemplating the installation of a picture system as permanent equipment on its passenger planes.

In these tests successful transmission of weather maps and sketches of airports were made to a plane in flight. Slight modifications of the original apparatus were necessary to adapt it to use on board, but the essential principle was unaltered.

Attempts are being made at present to transmit pictures from the plane to the ground, thus completing a two-way system. Special apparatus for exclusive use in the air is being designed with a view to its permanent installation. It is expected that the new system will be ready for use when the tests are completed, and that it will make a great contribution to safety in flight.

about the car. In the first place there are only two pedals: the brake and accelerator. There are also an emergency hand brake, a small button to reverse the motor, and an electric starter button. The clutch and gear shift are eliminated, permitting the driver to have two hands on the wheel for safety. Because of the electrical equipment the motor will start smoothly and gradually no matter what amount of electricity be generated. The car is accelerated to a maximum of 40 miles per hour by the simple expedient of accelerating the gas engine. Engineers claim higher speeds easily possible.



Courtesy *Railway Electrical Engineer*

PORTABLE AIR HOIST

The double cylinder air hoist is shown with the cradle in its fully raised position.

An Underwater Tunnel now under construction in England will be the largest in the world. It will connect Birkenhead and Liverpool, which are 2.9 miles apart. The tunnel will carry four lanes of traffic and have a large space for air ducts. At the present time it is planned to provide a space below the roadway for the use of street cars.

A preliminary tunnel was built in 1928 and shortly after plans were made for this enlarged tunnel. The main tunnel carries a 36-foot roadway and has a double approach on each side. Ventilation will be taken care of by three plants at each end which will be capable of supplying 4,000,000 cubic feet of fresh air per minute.

A Gasoline-Electric Automobile has been delivered to one of the country's rich men. Power is provided by a generator which is mounted directly on the flywheel of the gasoline engine. Electricity thus generated is transmitted to an electric motor which drives the wheels through a worm gear.

There are several notable features

A Portable Air Hoist has been developed to facilitate the handling of heavy axle generators for electric locomotives. This apparatus, of only 33 inches wheel base, may be used to transport, and to hold in position under the cars, heavy and cumbersome generators, which are placed in the cradle.

As may be seen in the illustration, the mechanism is operated by a double cylinder air hoist with one inside the other. This type of action permits a greater travelling range and at the same time a lower minimum height. The lower part of the V-shaped cradle is 12½ inches above the floor as a minimum and may be raised to a height of 21½ inches.

The power is supplied by a ⅜-inch air hose from the shop air supply. A valve prevents sudden falling of the hoist in case of failure of the air supply.

Giant Trailers are becoming a common sight in many large cities since the laws forbid huge pieces of machinery to travel on the pavements under their own power. The huge trailers can carry as much as 100 tons and have eight wheels with sixteen solid rubber tires. The vehicle is built with two separate units of four wheels each. These double rocking units are pivoted so that the wheels follow all depressions and protuberances in the road. The huge capacity calls for special brake bands which are unusually large.

The trailer is so large that it dwarfs the truck which draws it. However, it serves its purpose by distributing the load evenly over the road and keeping the paving in good condition.

A Gasoline Driven Welding Generator has been developed especially for electric welding at points remote from any power supply. The generator is a new 300 ampere type designed for welding. It is mounted on a steel frame and is flexibly coupled to a 30 horse power four-cylinder gasoline engine. The generator control panel is mounted on top of the generator frame and contains a single dial rheostat. The entire equipment is protected by metal covers which make the device available in all weather and by the addition of running gears the unit can be made portable.

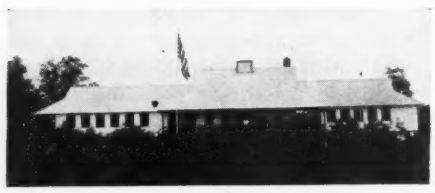
The Moisture Content of wood can now be accurately determined by use of an electric device recently introduced. The manufacturer states that the electrical conductivity of wood, measured across two contact needles is, with the exception of a few rare cases, an accurate measure of moisture content. The device weighs but 20 pounds and is equipped with 10 feet of electric cable, small lamps used when sorting wet stock, and a milliammeter for use with dryer stocks. The current supply is obtained from dry batteries which are contained in the case of the instrument.

Traffic Relief has been secured by the grade separation where the New York-Philadelphia highway crosses another main artery. Although this unique arrangement requires a great deal of space it permits a car to go in any direction by making only right turns and without crossing any traffic whatsoever. This permits a steady flow of traffic, no regulation being necessary. Although the idea is elaborate it has accomplished its purpose and contributed to the safety of automotive travel.

Departmental Notes

DEPARTMENT OF MINING AND METALLURGY

THE past year has seen an increase in the enrollment in this department and much interest in various branches is being displayed by students registered in other departments. The latter is particularly true of the work in Physical Metallurgy. Our laboratories for the work along this line are recognized as among the best equipped in America and, during the past term, no less than 250 men have carried on work in them. No less than twenty men, several from other departments, are engaged in researches in physical metallurgy.



SUMMER MINING CAMP
ADMINISTRATION BUILDING
This camp is situated in the rich magnetic iron ore field of New Jersey.

Metallurgy

The most important development during the past decade in the field of physical metallurgy is nitriding; important because it makes possible longer life for motors and wearing parts in the automotive and aviation industry. Nitriding is the process by which special steels can be surface-hardened at a low temperature by the action of ammonia. This process has many advantages over case-hardening in that heat treating of the articles is done before nitriding and so low a temperature is used that no appreciable warping or distortion occurs, provided the strains produced in machining or hardening have been removed. As average indications of the wear resistance of this product, we may cite the following examples: In the automotive industry, nitrided cylinders sustained a wear amounting to but one-twentieth the wear shown by cast iron cylinders over a distance of 18,630 miles; In the aviation industry during 100 hours operation nitrided cylinders showed no wear, while heat-treated steel cylinders showed appreciable wear as evidenced by the fact that oil consumption of the nitrided motor remained constant throughout the 100 hours, while oil consumed by the heat-treated steel cylinder motor increased 300 per cent. Not only are members of the staff carrying on research in this field, but several theses, graduate and undergraduate, are in progress on the various phases of nitriding.

Professor Homerberg is one of the leading men in America on the subject of nitriding. He has already spoken, or is scheduled to speak on this subject, to no less than fourteen chapters of the American Society for Steel Treating and at two National Conventions at Cleveland and Detroit.

The importance of physical metallurgy to industry cannot be overestimated. Professor Williams has given one of the Popular Science Lectures under the auspices of the Society of Arts, and the subject of his lecture gives a fine idea of how interesting a subject is physical metallurgy, for it is entitled "The Romance of Metals."

During 1929 Professor Waterhouse served as chairman of the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers. Under his guidance, that Division conducted sessions in New York and held a special meeting in Cleveland. Recently he has been appointed chairman and director of the Iron Alloys Committee of Engineering Foundation, a committee faced with the momentous task of making a critical survey of the world's literature on alloy steels and cast irons, and issuing two series of books, one for research workers, the other for shop superintendents.

During the summer of 1929, Prof. C. R. Hayward spent about six weeks in an intensive trip to about fourteen different metallurgical plants in Illinois, Texas, Utah, California, Arizona and Old Mexico.

Mining

Progress is being made along the lines of geophysical prospecting and, through the coöperation of several of the active companies, our equipment for field studies has been built up so that not only are we prepared to teach the elements of these scientific methods of prospecting, but opportunities for research can now be offered. In connection with the Summer Surveying Camp at Dover, New Jersey, it is now found practical to carry on some magnetic prospecting in conjunction with the regular surface and underground surveying in areas particularly suited to the study of magnetic and electrical prospecting. During a portion of the summer of 1929, Mr. F. L. Foster was in Eastern Canada studying the methods and field procedures employed by the Radiore Company in their electrical prospecting.

More interest is being displayed in the courses in petroleum production. For the past five years Professor Mann has spent his summers in the oil fields studying petroleum practice and collecting data for instruction purposes. In 1929 he conducted the Oil Field Visits through Pennsylvania where a group of students in petroleum production gained first-hand acquaintance with oil fields practice.

It is the aim of every member of the staff to keep up with all of the advancements in practice along his line. It was with this end in view that Professor Locke, obtaining leave of absence from September through December, attended the World's Engineeering Congress in Japan. As part of his trip, he visited numerous mining districts of Michigan, Missouri, Colorado, Montana, Idaho, British Columbia, California, Utah and Arizona, studying mining and milling practice. While in Japan he found time to visit a number of the principal mining districts there.

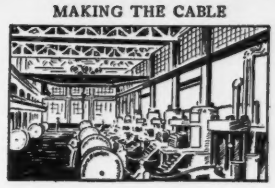
Many opportunities are offered for graduate study in mining. Professor Hutchinson has charge of courses in mine valuation, mining economics and advanced mining engineering. The study of mine valuation is carried on by the case system, reports of mine examinations are supplied from the files of active engineers, and the students make their own interpretation of these reports. Mining economics offers an opportunity for a study and interpretation of the annual reports of mining companies over a period of years, while the course in advanced mining engi-

(*Continued on page 20*)

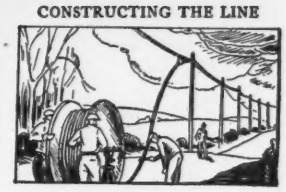
STUDENTS READY TO LEAVE CAMP
Surveying and mining practice made up their two months' work.

TESTING THE MATERIAL

MAKING THE CABLE



CONSTRUCTING THE LINE



Winning the war against weather

In the telephone business, research man, manufacturing engineer and construction supervisor are carrying on a successful war against the unruly elements, enemies to service.

Cable, for example, housing many circuits and covered with protective coatings of proved strength, withstands storms which might seriously threaten open wire lines.

Thus in the Bell System growth is intensive as well as extensive, improving present facilities as well as adding new ones. And there is no end to all this development.

BELL SYSTEM

A nation-wide system of inter-connecting telephones

AMERICAN TELEPHONE & TELEGRAPH CO. AND ASSOCIATED COMPANIES — BELL SYSTEM

"OUR PIONEERING WORK HAS JUST BEGUN"

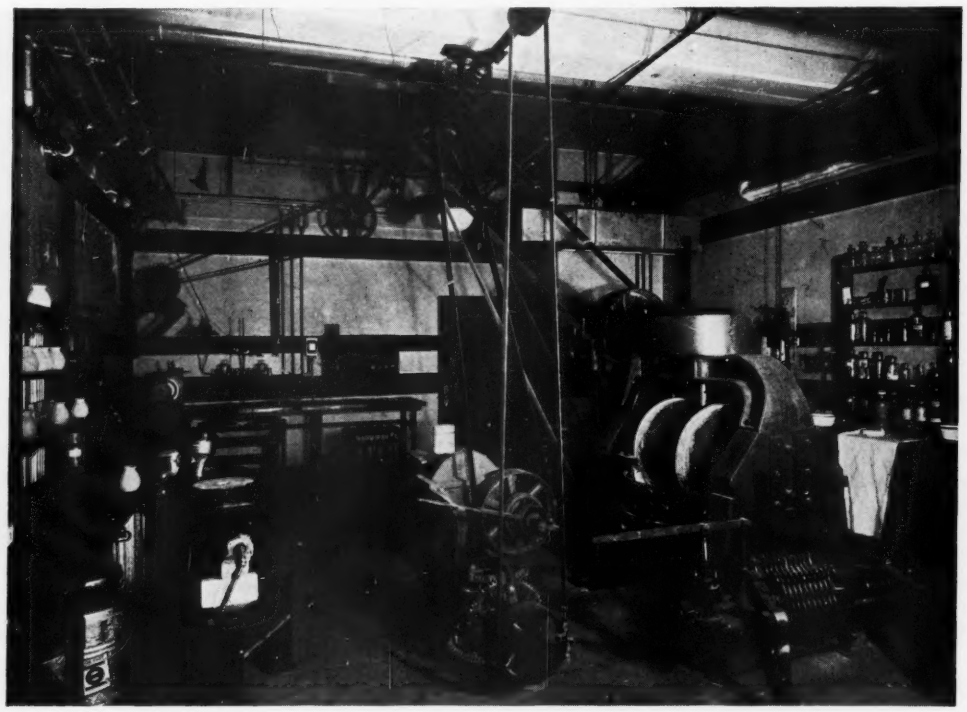
A Glimpse of the Ceramics Industry

(*Continued from page 9*)

tor which have shown high working efficiencies. A considerable amount of research has been done on the theory and design of high temperature kilns. Means of measuring gas flow at high temperatures were developed, and the use of models was employed to aid new design. A study was made of the stresses in kiln crowns, and this led to the adoption of the catenary arch which has proved far superior to the circular arch for most installations. Most of the development work which has been carried on has been published in the *Journal of the American Ceramic Society.*

Some of the researches now being carried out include an investigation of the New England clays. Previously there has been very little done on the technical study of these clays, and some interesting facts have been brought out which may have industrial importance. Another investigation is the study of the time and temperature effects on the maturing of white ware bodies, that is, we wish to determine whether it is possible to burn a body as well in a short time at high temperature as for a longer time at a lower temperature. These facts are of the greatest fundamental importance to the industry in the speeding up of the manufacturing process. It is also hoped to study the life history of glazes, especially in regard to the crystals developed, their solution, and the bond between the glaze and the body. Another interesting piece of work is a fundamental study of ceramic colors. At present we know very little as to the reason why traces of certain oxides give brilliant colors to glazes.

Ceramic students here are fortunate in having the opportunity to make use of the excellent equipment and instruction in fields of physics and chemistry which are becoming of more and more importance to modern ceramics, that is, colloidal chemistry, X-ray analysis, petrography, and thermal and optical measurements.



THE CERAMICS LABORATORY

This laboratory is well equipped for taking care of all usual small scale commercial processes.

The courses now offered which lead to a Master's degree are:

1. Theory and Practice of Fundamental Ceramic Processes.
2. Physical Properties of Ceramic Products.
3. Optical Ceramics.

The subject of Physical Properties of Ceramic Products will include the various methods of determining the properties of finished ceramic articles. The influence of manufacturing methods on these properties is taken up in order to bring out effective methods of control.

Optical Ceramics is primarily a laboratory subject in which the methods of petrography are applied to the study of ceramic products and raw materials, such as clay, cement, glass, porcelain, refractories, etc.

This course is open to graduates of technical schools who have the proper prerequisite training. Students who have had no undergraduate work in ceramics may take the subject of Elementary Ceramics during the preceding summer.

The course also includes other advanced subjects which apply to this field, such as X-ray and Crystal Structure, Physical Chemistry, Colloids, Photoelasticity, etc.

The work in Fundamental Ceramic Processes takes up the theory and practice of forming, drying, and burning of clay articles, such as white wares, refractories, terra cotta, etc. The principles involved in the manufacture and use of glass, cements and abrasives will also be discussed. The principles of kiln and furnace design are discussed and practical examples will be analyzed.

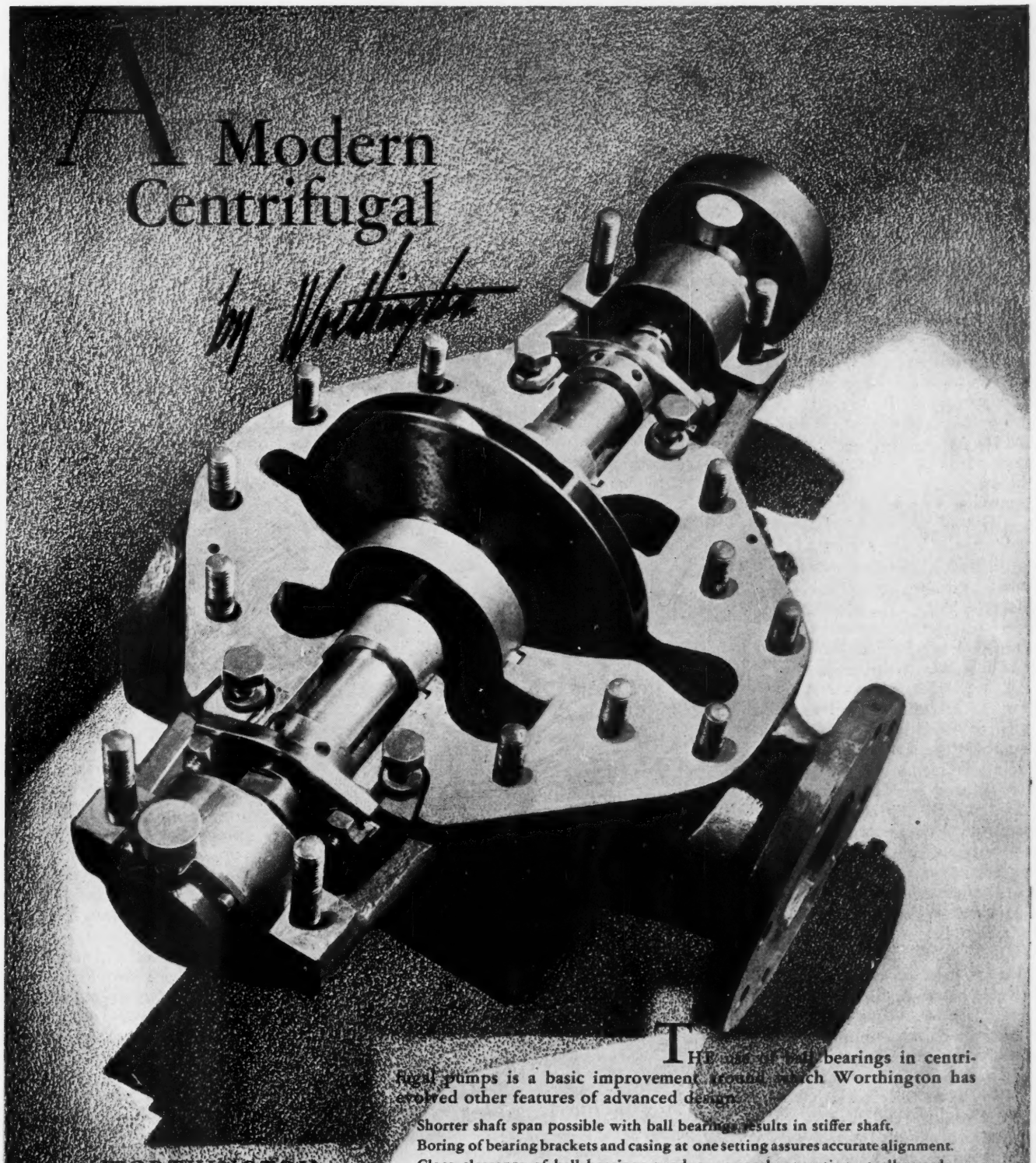
Departmental Notes

(*Continued from page 18*)

neering covers any of the numerous problems encountered by the mining engineer on which the student desires to specialize.

Mining and petroleum engineers live an outdoor life while gathering nature's mineral wealth from the far corners of the earth; the production metallurgist deals with the smelting of ores, machinery, furnaces and gigantic plants; while the physical metallurgist finds his adventure in microscopic study of finished metals and alloys in the laboratory. Thus, the student in the Department of Mining and Metallurgy may choose a profession which will place him in any environment he may desire. W. S. Hutchinson '92.

A Ball Bearing Spring Shackle which has proved very reliable, consists of two side links held together in the middle by a bolt and recessed at both ends to form bearing cups. The inner race of the bearing is formed by the ends of the shackle pins, one of which is fastened to the frame of the car and the other to the spring. Rattles and squeaks are eliminated, as well as the need of lubrication.



THE use of ball bearings in centrifugal pumps is a basic improvement around which Worthington has evolved other features of advanced design.

Shorter shaft span possible with ball bearings, results in stiffer shaft.
Boring of bearing brackets and casing at one setting assures accurate alignment.
Close clearance of ball bearings produces smooth operation at all speeds.
These mechanical advantages, combined with improved hydraulic design, result in higher efficiency and lower maintenance cost . . . hence lower expenditure in the long run.

Bulletin W-310-B1A describes Worthington Ball Bearing Pumps in detail.

May we send you a copy?

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GAS ENGINES
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Worthington on the Air

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WORTHINGTON

The Laws of Fatigue in Racing

(*Continued from page 13*)

to practical deductions, requiring careful attention to avoid possible mistakes.

First. If we plot for running men the record times against distances, or T against L on log paper, we shall probably draw a straight line through the 500-meter record of 65.5 seconds at an upward inclination of nine to eight, corresponding to the 9/8th power. Examining the plotted points in detail, with respect to the straight line drawn along them it will be evident that some lie right on the line, while others deviate above, and the remainder below. Those that deviate above are relatively longer, and those that deviate below relatively shorter in time than those right on the line. It is reasonable to regard the records with deviation above as more vulnerable than those deviating below.

Commencing with the shortest run — a sprint of 20 yards (18.3 m.) the recorded time is 2.8 seconds. According to the law, as represented by the straight line, the time should be 1.55 seconds — a large discrepancy. It will be remembered, however, that the sprinter has to get into speed from rest and make his run all in less than three seconds. It is only reasonable that there should be delay from inertia. The plotted record lies far above the line; but in this case the record does not encourage so much hope of improvement as might appear at first sight.

As the courses lengthen the upward deviations from the straight line dwindle, until, at 100 yards (91.4 m.), the deviation has disappeared. From this point, as far as 400 meters, the deviations are downwards, corresponding to relatively superlegal speeds. These distances are usually run at full speed as closely as it can be maintained. Whatever their future status may be, these high-speed records do not invite attack. Only two records within this range seem to have been broken during the last twenty years; namely, the 120-yard and 130-yard records, which have been clipped by a tenth of a second.

Between 500 and 1,500 meters, some of the records are very close to line; but others are above the line and look therefore vulnerable, especially some of the newer metric distances.

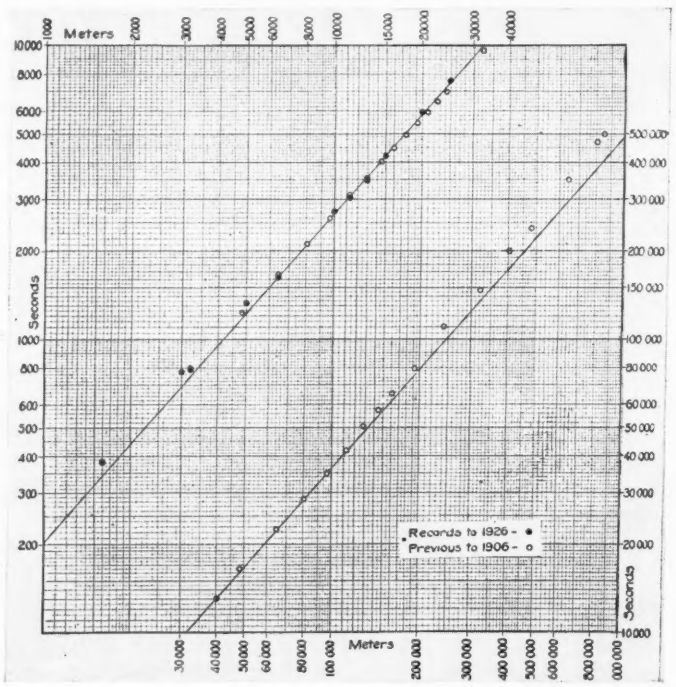
Between 2,000 and 5,000 meters, there are several deviations upwards. From 5,000 meters to 40,000 meters, the points lie fairly close to the line.

Beyond 40,000 and up to 100,000 meters, distances seldom contested, there are marked upward deviations.

During the last twenty years the records have been improved in the following running events — 1, 2, 3, 4, 5, 6, 8 and 10 miles.

Second. Although the average speed V of a racer gives us no accurate information as to the steadiness or uniformity of speed during the run, yet it is reasonable to infer that *it is advantageous for a racer to keep his speed as nearly uniform as possible from beginning to end of the race.* This deduction applies particularly to long races. In sprinting up to say 500 yards or 450 meters, it is necessary to run at practically top speed all the way. Such races do not last more than one minute. In longer races than these, the speed has to be regulated, in accordance with some working theory of best physiological action. On any theory, it is reasonable that the last lap should be made at the best possible speed, or with the greatest acceleration at command, so as to reach the goal, exhausted. If, however, it becomes possible for the racer to accelerate materially over the last lap, it would seem that he has misjudged his previous speed, and that he should have kept a better gait.

There are a few world-record makers who have made records over courses of very different lengths. For example, Nurmi is credited with the record for the 1,500-meter run at a mean velocity of 6.7 meters per second, and also with the 10,000-meter run at an average of 5.5 meters per seconds. It must be supposed that in the shorter of these, the 1,500-meter run, he reached the winning post temporarily exhausted. Consequently he could not have run any 1,500-meter stretch of his 10,000-meter course at a speed as high as 6.7 meters per second. If, in any part of a long race, the runner accelerates above the average speed V proper for the world's record, he has to pay for the spurt at the appalling rate of the inverse eighth power of the greater speed so far as relates to his available running distance, or as the inverse ninth power for available running time. Unless, therefore, new statistical evidence can be adduced to the contrary, it appears reasonable to infer that a record-making runner must hold his speed steady at that which will just bring him exhausted to the goal. A generation ago this was not the usual theory of running. It was generally held that the speed should be relatively high in the first and last quarters of the race, with a distinct diminution in the second and third.



WORLD'S WALKING RECORDS
The records of the longer, relatively uncontested distances show good chance for improvement.

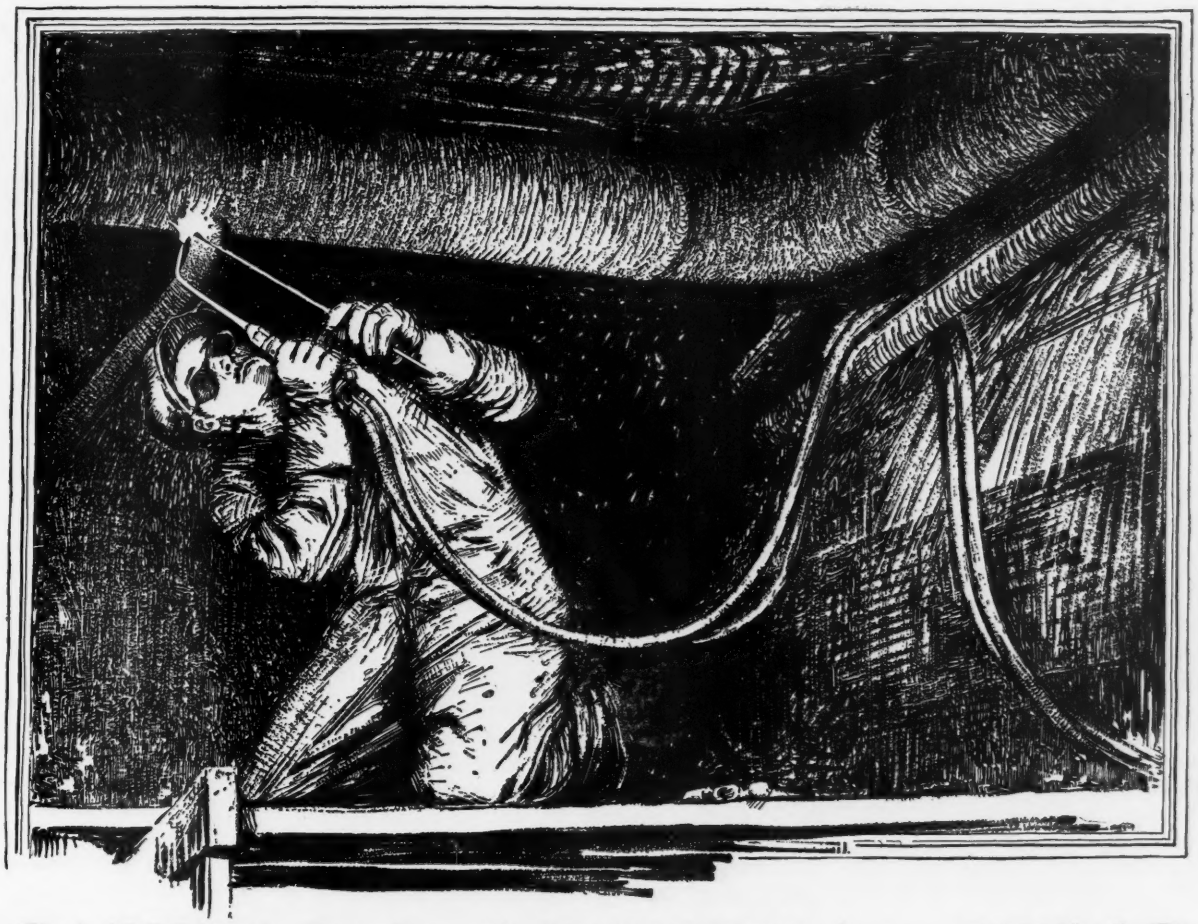
Precision of Different Classes of World's Records

We may regard the precision of a series of racing records as fixed by the mean deviation of the records from their properly selected straight line on log paper. With all the points very close to the line, the precision of the series would be high. From this standpoint, horses have more precision than men; *i.e.*, horses racing under the control of jockeys show more professional precision in their three gaits than men in any of their five. In the men's races, the relative precision is greatest for walking and next greatest in swimming. It is lowest for skating and next lowest for rowing. It seems likely that the lower precisions of rowing and skating may be due to the variable influences of wind during the contests.

Bicycling and Automobiling

The records thus far made in cycling are too irregular to sustain any simple rule. It would seem that the running conditions as to pacing, shielding, etc., must be standardized over a wide range of courses, before any reliable conclu-

(*Continued on page 24*)



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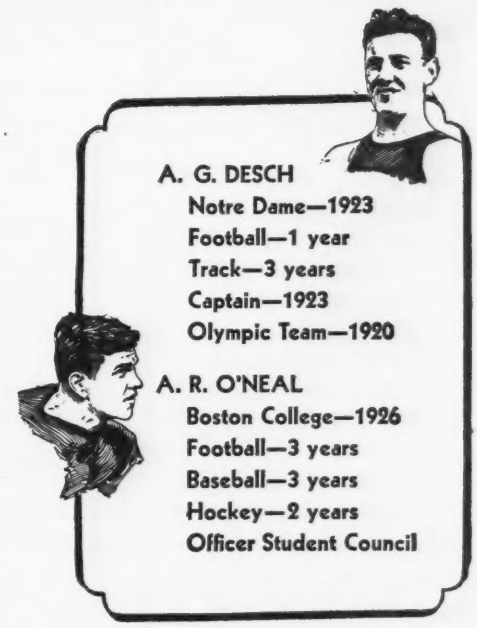

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Fatigue in Racing

(*Continued from page 22*)

sions can be drawn as to their "fatigue."

Automobile records are still subject to considerable change from year to year. At present they indicate that their speeds are practically constant, or devoid of fatigue, between courses of 10 and 400 kilometers. Below 8 kilometers there is very distinct reduction of speed due to inertia. Beyond 400 kilometers there may be some quasi-fatigue.

What are the Reasons for the Straight Lines on Log Paper

The answer to this question is not known. It depends upon the dynamic physiology of *homo sapiens* and *equus caballus*. It would be very interesting to learn the answer.

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Modern Concepts of Light

(*Continued from page 5*)

by the moving particles has the value of $h\nu$. But, the law holds also, that if the energy transition takes place in the opposite direction, that means if a system loses an energy W and produces light, the frequency ν of it is $\frac{W}{h}$. This law governs all the experiments in which any kind of light is produced, in radio-active phenomena, in the X-ray tube, in electric discharge tubes and photo-chemical reaction. It is one of the fundamental assumptions underlying Bohr's theory of the structure of atoms and Planck's theory of heat radiation.

The Einstein-Bohr frequency condition is in contradiction with the electromagnetic wave picture of light. All attempts to derive this law from or to reconcile it with the electromagnetic theory have been without success. It was therefore necessary to find a new conception of the structure of light. Again Einstein proposed a new point of view. Since light of the frequency ν is only able to loose and to gain energy of the constant amount $h\nu$, Einstein assumed that a light wave does not have a continuous structure, but is divided up in small light-packages, each one carrying this energy $h\nu$. Einstein proposed for this light unit the name "light-needles"; today we call them, "light quants" or "photons." This picture claims essentially that light has a corpuscular structure.

It is well known that previous to this Newton believed in a corpuscular structure of light. His theory had to be given up, because it could not account for the interference phenomena. The photon theory encounters the same difficulty. It seems impossible to conceive of any way in which two particles could destroy each other, as would be necessary to understand the dark spaces in interference pictures. Only a wave theory is able to explain this fact.

Through these developments the physics of light became one of the greatest puzzles. We had two seemingly incompatible theories, the electromagnetic wave theory explaining all the experiments of interference, polarization, scattering and reflections, and the corpuscular theory explaining all the atomistic actions of light, each theory able to explain one large group of phenomena, but unable to account for the other group of facts.

This extremely unsatisfactory situation in one of the most important branches of physics resulted in different desperate attempts to bridge the two theories. Of particular interest is the paper by Bohr, Kramers and Slater in which they assumed that the law of conservation of energy had only a statistical validity and the experiments of W. Wien who tried to investigate the radiation of single atoms in beams of canal rays. But the experiments of Boothe and Geiger disproved the theory of Bohr, Kramers and Slater, and the experiments of W. Wien did not furnish any clues for the solution of the difficulty. How badly scientists felt about this situation is illustrated by the fact that some were quite ready to introduce almost mystical assumptions. It was for example proposed that the light quants have a sense of predestination, that photons coming from a star, for instance, have many hundred years ahead of time knowledge that somewhere on earth a physicist is going to send them through a grating, and so they arrange themselves in such a way that they form interference patterns.

These really desperate assumptions can be excused if one realizes the importance of the problem. A clear understanding of the nature of light is not only important for optics, the branch of physics which is devoted to the study of light of all wave lengths, but has a great interest for science in general. To realize that, we have only to remember that our contact with nature is made almost exclusively with the help of light and our most sensitive organ, the eye. Especially in physics, where we aim to get accurate relations between the different physical quanti-

(*Continued on page 26*)

William G. Starkweather, M. E., Cornell '92 John B. Starkweather, B. S., M. I. T. '21

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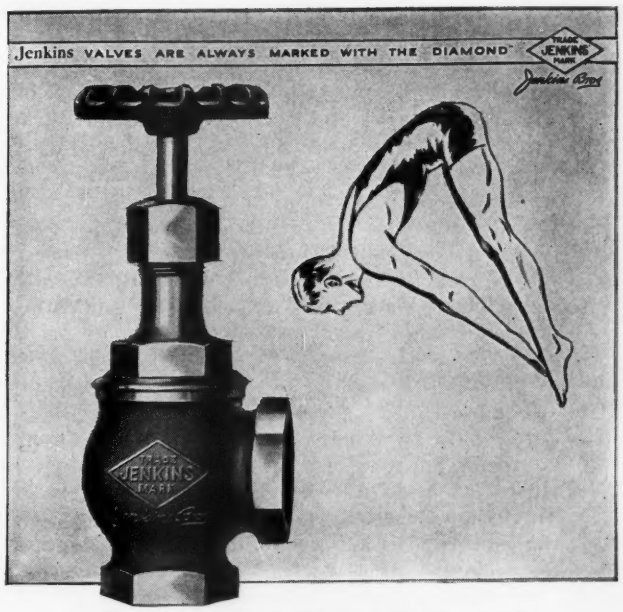

Fig. 108, Jenkins Standard Bronze Angle Valve, screwed

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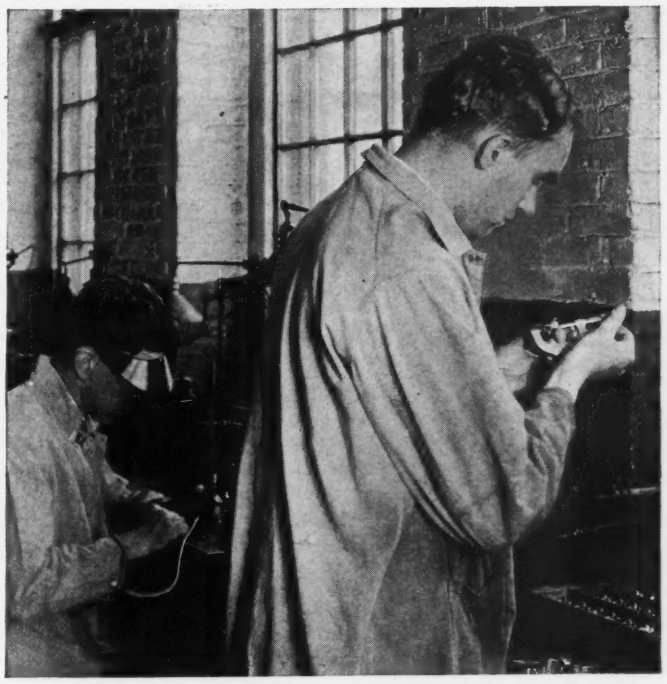

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Modern Concepts of Light

(*Continued from page 24*)

ties, we always have to make use of light; all our most accurate experimental measurements require in one way or another the help of light, be it radio-active γ-radiation, X-rays, visible light or radio-waves. To interpret correctly the facts which we "see" we have to know the properties of the messenger light.

This remark not only throws light on the general importance of the whole question, it also shows the difficulty of the problem. How can we get to the truth, if we do not know how reliable the messenger is, and how can we test the character of the messenger if he is the only one which can give us information? The answer is evidently: We cannot tell. That is the answer of the modern physicist to the question: What is light?

Should the physicist be ashamed of these modest and frank statement? Certainly not. He is in the last analysis only a human being, a small part of this immense mechanism called nature, and it is impossible for a small part of an organism to find out the law governing the whole, much less the purpose of it. Our human knowledge is limited by the fact that we are human, and our physical knowledge is limited by the experimental methods and our human senses.

Such a statement sounds rather fatalistic, still it is perhaps the deepest thought which modern physics has created. This "we cannot tell" means a change of the phyilosophy of our scientists. But it does not mean a pessimistic giving up of hope, it is an experimentally verified principle.

In order to explain how the physicist came to the conclusion that we will be unable to decide whether light is a wave or a corpuscular phenomenon, I have to relate some of the history of the theory of atoms. The investigations of Rutherford led to the picture that an atom consists of a very small positively charged nucleus, in which practically the entire mass of the atom is accumulated, and a number of negative electrons spinning around the nucleus. The work of Bohr and Sommerfeld came to the conclusion that the motion of these electrons was not only governed by Newton's law of mechanics, but moreover that certain so-called quantum conditions were of primary importance. While these quantum conditions could very well be mathematically formulated, it was not possible to give any definite physical reason for their existence. The explanation of this problem is due to a young French physicist, Louis de Broglie, who received for this work the Nobel prize for 1929. He introduced the very surprising assumption that the electron is a wave, and that the quantum conditions represent conditions for interference maxima. This idea was destined to be of tremendous influence. In short succession Davison and Germer, Rupp and G. P. Thompson produced interference phenomena with help of electrons. Schrödinger generalized DeBroglie's idea, and was able to explain with help of it some of the most difficult problems of Atomistics. It was definitely shown that the electron, which in all former experiments could be considered as a particle, manifested in a large number of other phenomena the properties of a wave. Through this discovery the theory of the electrons had reached exactly the same state as the theory of light. It became evident that a curious dualism is ruling nature. All the elements of the physical world can act in some

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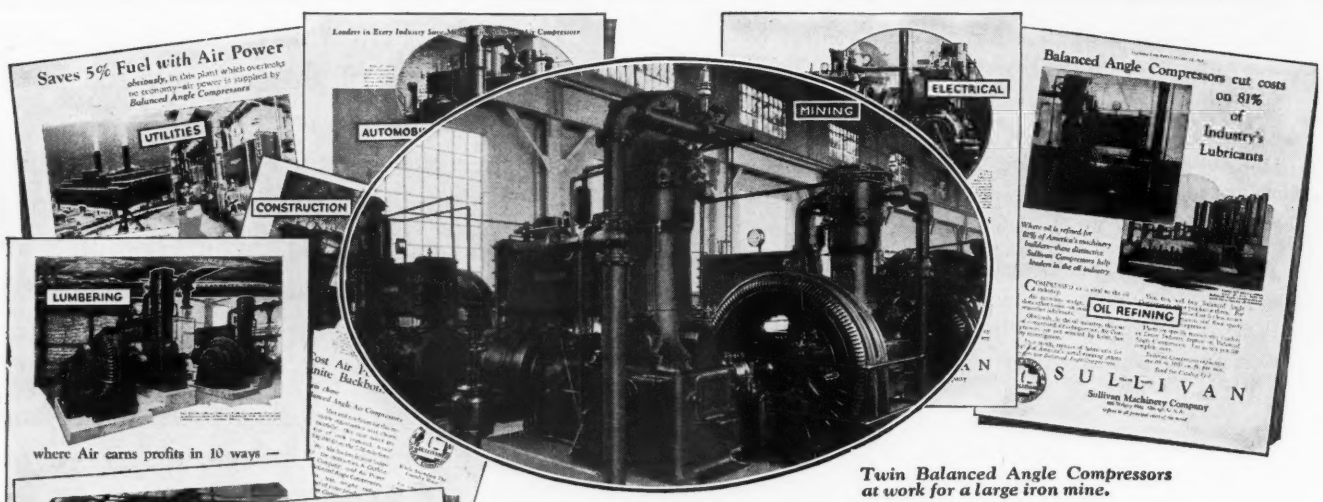

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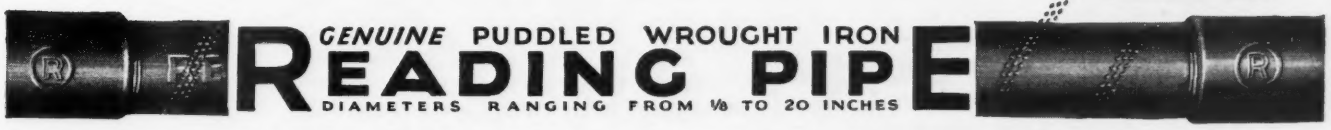

Science and Invention Have Never Found a Satisfactory Substitute for Genuine Puddled Wrought Iron

Modern Concepts of Light

(*Continued from page 26*)

cases like corpuscles, in other cases like wave phenomena. A first explanation of this dualistic behaviour was attempted by Schrödinger. He showed with help of mathematical methods first invented by Hamilton that the mechanics of a corpuscle can be considered as the limiting case of a wave phenomenon. If we have to deal with large scale problems a wave behaves like a particle, a fact well known in the case of optics. Light passing through a large slit forms a parallel beam like a stream of particles, while with a narrow slit the wave nature manifests itself through interference fringes. Schrödinger's work leads to the assumption that the real nature of physical elements would be a wave character and that the corpuscular character is only imitated in large scale experiments. Unfortunately this idea does not work, since it leads to the result that a single particle should, as time goes on, spread out in space, which is evidently contrary to the behaviour of electrons.

The final solution was given by the Göttinger physicists Born, Jordan and Heisenberg. They consider the elementary units of the physical world, photons, electrons, and protons as corpuscles. To explain the interference phenomena it is necessary to give up the principle of causality.

The principle of causality means that if we know at one given moment accurately the state of a physical system and all the forces acting upon it, then we are able to determine accurately the state of the system in the next moment. This principle is the fundamental of the classical physics, expressing the belief that there are definite laws connecting the present with the future. Born and Jordan realized that this principle is not necessary for the existence of physical laws. They believed that the laws of nature are not so definite, that they do not accurately determine the future, but only approximately. The laws give only the probability of what is going to happen, they do not definitely state that a particle under the influence of gravity will fall, but only that it is the most probable thing that will happen; the particle might happen to rise, but this is very improbable. According to Born and Jordan nature has a certain degree of freedom; it is not entirely restricted by accurate laws, but only partially restricted, in so far that the laws determine the relative probability of the different possible changes. These probabilities now turn out to be wave functions and this is the solution of the dilemma between corpuscular and wave theory. In the case of light the path of the photons is not strictly determined. The only law ruling its motions gives the probability of the different paths. This law, therefore, gives a definite statement only if we are experimenting with a large number of photons, as we always do in ordinary optical experiments. Since the probability is a wave function it is possible to explain now the interference pattern with help of a corpuscular theory. The probability law guides a large number of particles in the region of interference maxima and only a few come in the regions of interference minima.

This fact, that we cannot find definite laws for the happenings in nature, but only probability laws, has a very definite reason. This reason has first been detected by Heisenberg and Bohr, and it is simply the fact that we are human, that we are restricted by our experimental means and our senses. Heisenberg saw that it is not necessarily correct to say that there is no principle of causality. There may be definite laws connecting the present and the future, but we will be unable to find these laws. Because in order to investigate how a physical system changes under the influence of certain forces we must first be able to define the initial state of the physical system. First we have to know the present state of a light wave, of an electron, etc., before we can tell what is going to happen to it. The real reason that we cannot tell how a photon is going to move is not because there is no definite law determining this motion, but it is the fact that we cannot know at any instant the exact position of the photons. Heisenberg calls this fact, that we are limited in the accuracy of our measurements, the principle of indeterminism.

It may seem that this principle of indeterminism is a pessimistic opinion about the present state and the future of our experimental methods. But that is not so. This principle has not resulted from pure philosophical speculations, it is based on an experimental fact, the Compton effect, discovered by Prof. H. A. Compton in Chicago.

Compton shows that if a photon hits an electron two effects occur: The electron is given a velocity in a certain direction, and a secondary photon is produced. This secondary photon has a different frequency and a different direction than the original one. Frequency and direction stand in a definite relation to each other and to the direction and velocity of the recoil electron. One of these four elements determines the three others, but this independent element, for instance the direction of the secondary photon, remains undetermined. The experiments show, indeed, that the light is scattered in all directions. The Compton effect has been very important in different respects. First, it is one of the best proofs of the corpuscular structure of light. The relation between the velocity of the recoil electron and the direction and frequency of the secondary light contradicts the wave theory, but is in agreement with the theory of photons. Second, the effect demonstrates the failure of the principle of causality. There seems to be no law fixing the direction of the secondary photon, all directions are possible but some are more probable, which is manifested by the fact that the intensity of the scattered light varies with the direction.

The Compton effect is the root of the principle of indeterminism which states that we cannot formulate definite laws because we never know accurately the condition of an elementary particle. Indeed: How can we determine with the highest accuracy the position of an electron? With light. But according to Compton the light will move the electron in a way only partly deter-

(*Continued on page 30*)

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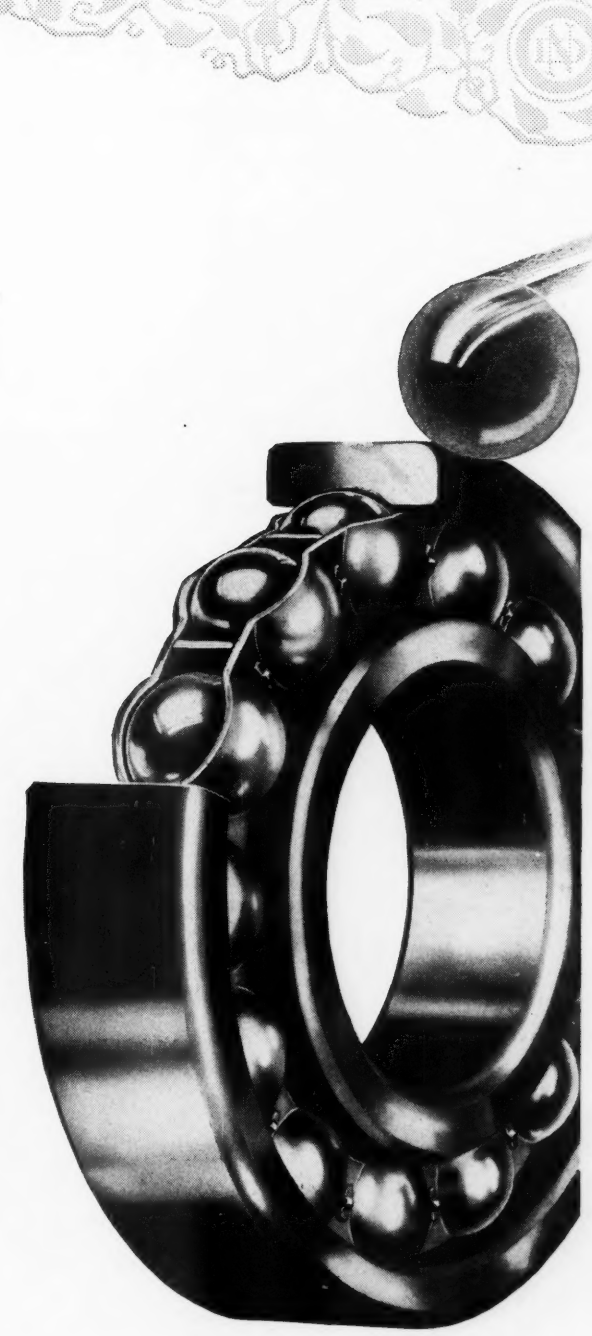

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Modern Concepts of Light

(*Continued from page 28*)

mined. Hence, the experiment of measuring the position changes the position in an undetermined way, and the calculation shows furthermore, that the higher we chose the frequency of the light in order to be able to make more accurate determination, the larger is the change in the position of the electron. We can therefore never determine where the electron really is, the attempt "to look at it" chases it away, and all we can tell after the measurement is: It must be within a certain region where "we last saw it." As long as we have no other experimental tools than light to fix the position of an electron, we cannot find the laws of nature.

As a résumé we might say: Since every measurement requires a certain energy exchange between the element we want to investigate and our senses, all physical quantities can only be determined with a certain degree of inaccuracy. This limited accuracy precludes the formulation of absolute laws in the sense of the principle of causality.

It is of course still possible that nature is ruled by causality. For instance, in the Compton effect it would be feasible that some element, for instance a phase relation between the electronic wave and the light, determines for every impact the direction of the secondary photons. But this quantity, whatsoever it may be, is not within reach of our experiments. To find this quantity is only guesswork. We do not know what it is, and it really does not matter, since we could never experimentally verify if it plays the role or not. The invention of such a theory which would satisfy causality, and perhaps one could even find more than one, would only satisfy our esthetical feeling, but it would not be a contribution to physics. Because the purpose of physics is only to establish relation between observable quantities. This principle formulated first by the physicist and philosopher Ernst Mach has been the leading idea which saved physics from the inconsistency of the classical theories. This principle is the fundamental of Einstein's theory of relativity, and if the theory of light shall not become metaphysics we have to stick to it.

The nature of light is still unknown. Its structure is probably corpuscular. The photons are guided by probability waves. The polarization effects are possibly in connection with a spin of the light quants. But at present these are only speculations.

Prize Essay

(*Continued from page 7*)

the accident reports of the Department of Commerce, errors of pilots have contributed the largest percentage of the causes of accident.

Under certain conditions, air transportation, as a means of passenger travel, is decidedly safer than railroad transportation. During the decade following the World War, travelers between Berlin and Moscow were advised to travel by air, it being considered safer and more convenient due to disrupted conditions on the ground.

A similar case is the recent revolution in Mexico. Travel by rail from Mexico City to the United States border was dangerous, but passengers were transported in safety and with reliability both ways by air.

This also holds true in times of natural catastrophes, when the airplanes are intact, there being no railroad tracks or bridges to be destroyed or damaged.

During three years ending 1927, Imperial Airways, Ltd., of Great Britain, carried over 52,000 passengers without a single fatality. In the year 1927, in the United Kingdom there were 419 deaths on the railroads, or one death for every 625,298 passenger train

(*Continued on page 32*)

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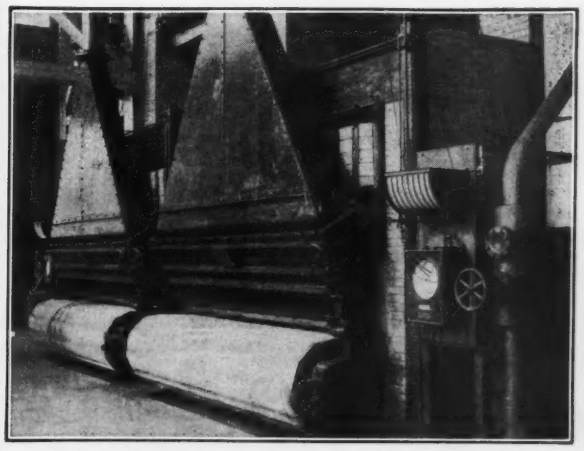
Write for Bulletin No. 81B

Bailey Meter Co.
Cleveland, Ohio



Bailey Meters at Western Electric Co., Kearney, N. J.

The James Means Memorial Prize Essay

(*Continued from page 30*)

miles. For the period of time considered, the airways were safer than were the railroads.

There is little lighter than air or airship flying in the United States, and no organized lighter than air line. In Europe, however, lighter than air lines have made remarkable records for safety. Small commercial rigid airships operated in Germany both before and after the war, carrying 37,000 passengers without an accident or mishap.

Airways are now going through a period comparable to that of the railroads nearly one hundred years ago. In an article appearing November 15, 1835, in *John Bull*, an English paper, the author states: "Does anyone mean to say that decent people, passengers who use their own carriages, and are accustomed to their own comforts, would consent to be hurried along through the air upon a railroad, from which, had a lazy schoolboy left a marble, or a wicked one a stone, they would be pitched off their perilous track into the valley beneath . . . all their lives being at the mercy of a tin pipe, or a copper boiler, or the accidental dropping of a pebble on the right of way?" People today have the same fears regarding air transport. Let us see if this fear is justified.

For 1927 the causes of accidents in railroad operation to trains were given in this order: 1. Derailments; 2. Collisions.

Causes of derailments are shown under four headings:

1. Negligence of employees: 12 per cent of the accidents.
2. Defects in or failure of equipment: 45 per cent.
3. Defects or improper maintenance of way and structures: 24 per cent.
4. Miscellaneous causes: 19 per cent.

In explanation of the four headings, it was stated that the most frequent causes of derailments, under *negligence of employees*, were on account of switches being set in the wrong position, switches run through, running off derailers, and failure to latch or secure switch levers. Under this heading also came accidents due to disregard of fixed signals. An explanation of heading three stated that the most prevalent causes of derailments due to improper maintenance of way and structures are, first, insufficient, excessive, or uneven elevation of track, and improper alignment and surface of track. Broken rails is second in importance. And the spreading of rails comes third.

It will be seen from an analysis of these causes that headings one and three cover accidents which are caused by the necessity of railroad trains in their operation on the track, the neglect to keep in proper condition of any small part of which can cause an accident. A switch left open by an employee, or a rail which has been broken or spread, can wreck a train. The railroads still operate their lines, to a great extent, on one single track, as double tracks throughout their systems would be prohibitive in cost. That increases the risk of accident. Headings one and three together total 36 per cent — 36 per cent of the total causes of derailments, the most important cause for train accidents. These accidents represent conditions with which the railroads have to contend because they are limited to tracks. Airways, having no tracks, are free from this most important cause of accident.

The second major cause of accidents in railroad operation, *collisions*, is a type of accident with which aircraft have had but comparatively little experience. Those accidents which have occurred in the operation of aircraft could have been avoided by the laying out of traffic routes for air traffic at different levels and positions for the different kinds of traffic. This would eliminate a large percentage, although there would still be liability at airports where the traffic was congested. With organized airways, that would be at a minimum, however, and would certainly be less than that in railway operation, where trains are confined to a narrow right of way. In airways the danger would be primarily at terminals, while with railroads it is always present.

It is interesting to note that 88 per cent of those collisions which do occur in railway operation are caused by negligence of employees — train and enginemen. In air accidents for all classes of flying, the accidents due to all personnel — errors of pilot and other personnel, total 57.97 per cent. The railroads have a lower percentage for their first major cause of accidents, derailments, with 12 per cent. Yet the 36 per cent of accidents due to negligence of employees and defects or improper maintenance of right of way, together, might possibly be classed under *errors of personnel*, as track crews are maintained to look out for and repair dangerous conditions in the right of way. It is difficult to draw a line in such a comparison, however.

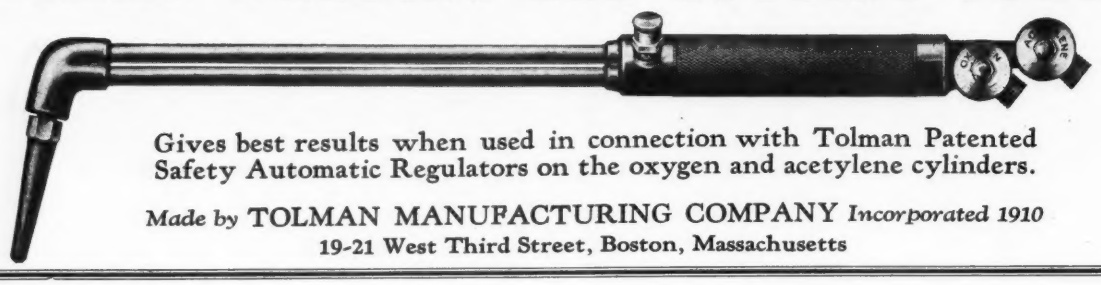
Weather conditions have practically no effect upon railroad operation under all conditions, but are of considerable importance in airway operation. Preventive work is being done by the establishment of organized weather service especially suited to the needs of air transportation. Such a service has been established on the air lines from Los Angeles to San Francisco, and is being adopted as rapidly as possible by other air lines. The National Air Transport Company plans a complex service: giving detailed reports and predictions for weather conditions two hundred miles to each side of their air route. With a knowledge of what to expect, dangerous conditions can be avoided, or flights cancelled if necessary. The present status of weather service for aeronautics is still in the pioneer stage, but much can be expected to develop.

Private Operation of Aircraft versus Private Automobiles

According to the Department of Commerce, there are 4,314 civilian-owned aircraft in the United States. Of this number, 128 were operated by

(*Continued on page 34*)

TOLMAN WELDING AND CUTTING TORCH



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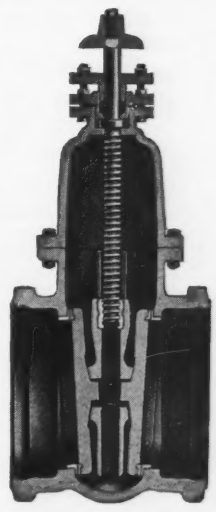

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The James Means Memorial Prize Essay

(*Continued from page 32*)

organized airways. The remainder were operated by private individuals, air taxi companies, schools, etc. During 1927 (eliminating fatalities which occurred on organized airways or in experimental flying), there were 113 fatalities and 165 accidents due to general private flying, or one fatality to every 37 planes, and one accident to every 25.3 planes.

In 1927, in this country, there was a total of 23,125,000 automobiles registered, and during that year there were approximately 25,800 fatalities from all causes, or one fatality to every 896 automobiles registered. Pedestrians composed about 65 per cent of all the fatalities, and about 50 per cent of the non-fatal injuries were due to the automobile operator.

Comparing the statistics of automobile with airplane operation, it will be seen that there are a great many more fatalities and injuries with airplanes than with automobiles. It is also interesting to note that automobiles have far more congested conditions to contend with in their operation than airplanes, due to the large number of automobiles on the roads and the limited roadspace they have to travel on. It is evident, however, that if airplanes can be brought to the point where they can be operated by private owners as efficiently as automobiles, that they will have a great advantage in being able to avoid pedestrian accidents. At the present time, however, if this basis of comparison can be taken as a criterion, airplanes are decidedly more dangerous than are automobiles.

It is a question in the minds of a good many well able to judge, whether or not the average individual will ever be competent to safely operate the airplane as we know it today. The high physical requirements which are necessary for safe flying are possessed by but a small proportion of the population, and unless the airplane can be made in some way semi-automatic for safe operation, it will always remain a decidedly dangerous vehicle for that class of operator.

Even if a private individual should have all of the necessary physical requirements for safe flying, it is today a business, and there is a great deal more to owning and operating a plane than just the actual flying: Proper upkeep and overhaul of the plane on the ground is just as essential for safe flying as is piloting. If the owner wishes to maintain his airplane in the best condition at all times, he requires a large amount of training. Paying skilled mechanics to do it for him can be done, of course, but it is expensive, and really takes the owner out of the average class today owning automobiles. A car may continue on its way with certain minor or even major troubles, and the passengers be perfectly safe. The worst that might happen to it is that it will stop. In the air, however, it is quite a different matter. It has been stated that there are only two kinds of airplanes: those in first-class condition and those in bad condition.

In order to have safe and reliable operation, one air transport company, in starting service, purchased seven airplanes and three engines per ship, or a total of twenty-one engines. Daily only two airplanes were flown, two other airplanes were on the ground ready to go if the need arose, and two other airplanes were arbitrarily marked "Out of Commission" and were undergoing inspection and repair. The seventh airplane was held out of daily

(*Continued on page 36*)

1855 • SEVENTY-FIFTH ANNIVERSARY • 1930

Watering 87,000 horses

On Horseshoe Lake near Oklahoma City, in a business-like, compact building, 87,000 horses (figuratively speaking) are stabled . . . nearly three for every family in Oklahoma City. For with the completion of a new unit of the Oklahoma Gas & Electric Company's power station at this point, the total generating capacity was raised from 46,930 to 87,130 horsepower.

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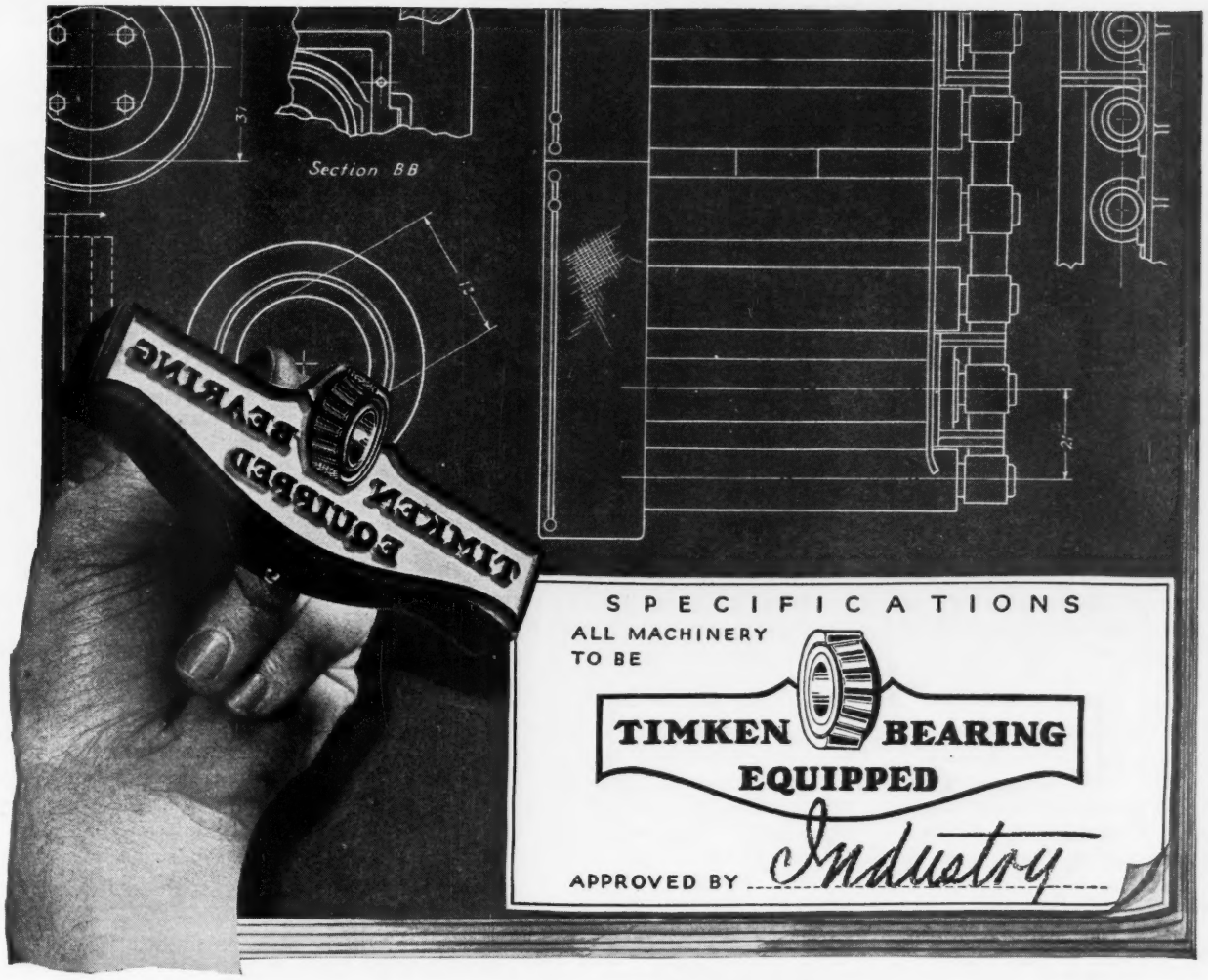

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TIMKEN *Tapered Roller* **BEARINGS**

The James Means Memorial Prize Essay

(*Continued from page 34*)

operation as an emergency measure, so that in the event of any major trouble developing in the other six, the system employed, of one ship in the air and two on the ground, would never be interfered with. The twenty-one engines were divided as follows: Seven in airplanes, seven completely overhauled and in reserve, ready for use, and seven in the shop undergoing overhaul. According to this plan, each airplane flew only six hours out of each seventy-two, and underwent inspection, repair and overhaul during the remainder of the time.

How many private owners will give their planes that sort of attention, or would be willing to spend the amount of time or money it represents? Yet those conditions are deemed essential for safe operation, and if they are not maintained, the penalties will be paid in loss of life and accidents.

If aircraft are to be used in safety by the average person, some new safety devices will have to be developed, or a type of aircraft different from the present airplane used. The Autogiro, while still in the pioneering stage, holds possibilities. While it, in common with the ordinary airplane, obtains its support from the relative motion of the supporting wing surfaces and the air, the difference is that the airplane, in order to obtain sufficient support, has a definite minimum translational speed, the Autogiro, through the relative motion of its supporting surfaces in rotation, obtains support even while the machine, as a whole, has little or no forward velocity. Thus the Autogiro has no definite minimum translational speed of support. It is, therefore, capable of landing in small spaces and at slow speeds, has no stalling danger, and is a safer type of aircraft for the average person. It is still in its experimental stage, but a large degree of success has been obtained, and further development is to be expected.

Many schemes have been put forward for making safer the present type of airplane, and a good many have been adopted. It is possible that the solution lies along this line. But for the present the airplane is not a very safe vehicle for the average man. As for the future, it cannot be foretold. We can, however, bend our efforts toward producing safer and more reliable airplanes. The results attained will be in proportion to the effort expended.

Building Foundations

(*Continued from page 11*)

excavated and boarded up, concrete walls were built between the caissons on both sides of the joint. The purpose of these concrete walls was to cut down the loss of air.

When the joint had been excavated to rock in this manner, it was filled with concrete placed through the air lock under pneumatic pressure.

These joints do not form an absolute watertight seal, but the little seepage that occurs is drained down to the bottom of the caissons and led to the drainage system under the cellar floor.

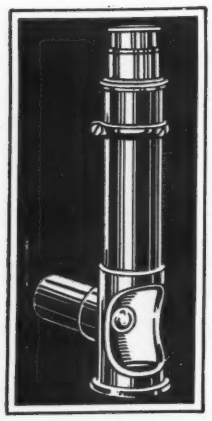
After the outside caisson wall was completed, the entire construction plant had to be removed, and a new set of derricks erected along the perimeter of the lot before the interior excavation could proceed.

The excavation was done mainly by hand, although for a time three Hoar Air Shovels were used, and the one cubic yard dump buckets were handled by eight derricks, which also placed the temporary timber bracing.

This timber bracing was placed as the excavation proceeded and consisted for the four upper tiers of double 12 by 12-inch sticks placed about 20

(*Continued on page 38*)

Why Modern Engineering Hinges on Optical Science



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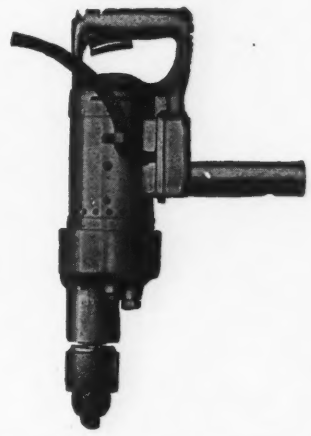

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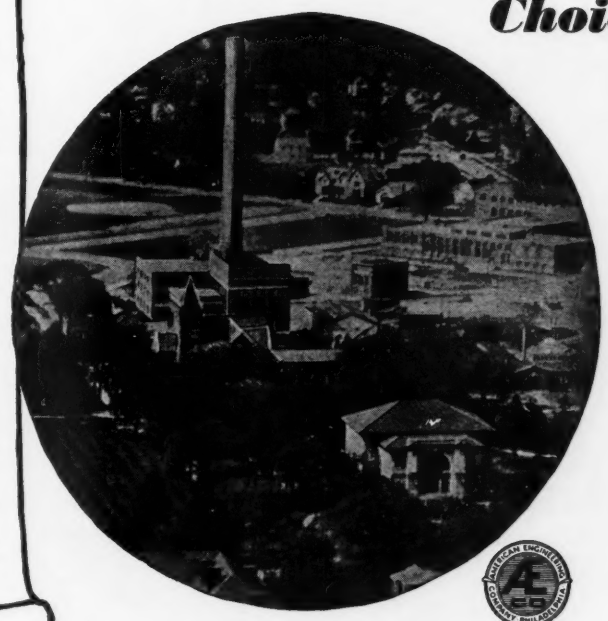

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Construction of Foundations for Tall Buildings

(*Continued from page 36*)

feet apart each way; the fifth tier, which was immediately above the "C" floor, consisted of four 12 by 12-inch sticks. The bracing was supported temporarily at intersection points by two 12 by 12-inch piles previously driven. Every tier of bracing was prestressed, before excavation was continued below it, by driving steel wedges inserted between steel plates, three sets of double wedges being used in each brace.

When the excavation had reached below the "C" floor the steel contractor erected the "C" floor steel, which was supported on an independent set of temporary timber piles. This steel was designed to take a great part of the pressure from the outside cofferdam wall and accordingly a considerable saving in temporary timber bracing was effected.

The steel struts were built in pairs, so as to admit the columns later without disturbing the struts. When the "C" floor steel was all in place and properly wedged up and supported, the excavation was continued to the "D" floor where another set of four 12 by 12-inch timber braces were placed, and when this had been wedged up, the excavation was continued to the bottom.

After the general excavation had been completed, the column piers were constructed on bed rock, and the column grillages and bases were placed. The columns were then lowered to place between the steel struts and the permanent connections of struts to columns were made.

In the construction of the foundations for the New York Telephone building no problems of underpinning adjoining buildings arose, as it was entirely surrounded by streets.

When heavy buildings, which are not supported on rock, adjoin a foundation operation, the underpinning is very often a serious problem as it is practically impossible to sink a pier to rock through quicksand or filled material without some settlement of the surrounding ground. The pneumatic method is no doubt the safest, but even when this method is employed it is necessary to support the adjoining buildings securely before sinking operations are started.

If the building to be supported is light the usual procedure is to support it temporarily on spur braces or needle beams inserted through the wall, then when the sinking operation is completed, jack or wedge the footing down to full bearing again, and the building will be resting on its old footing, although the bottom may possibly be at a slightly lower level.

When the building to be supported is heavy and the foundations resting on the soil, it will be necessary to practically provide new foundations carried down to rock or hardpan at least for the wall and columns immediately adjoining the new foundation operation and possibly also for some of the interior columns if there is any danger of these being undermined. This is often done by jacking down steel pipe piles 12 or 18 inches diameter to hardpan or rock, cleaning them out and filling them with concrete, then wedging them up to full bearing under the old footing. As this operation has to be done underneath the old footing, the head room is small and short lengths of pipe only can be handled. Usually 4-foot lengths are used, and these are spliced by inside sleeves to make up the required length.

These small diameter pipes have the disadvantage that they very seldom can be jacked to rock, they usually stop in hardpan, possibly on a boulder, and are liable to be undermined if a caisson or pier is to be sunk very close to them. In this case jacks must be placed on top of the piles under the footing and jacking kept up continually while the sinking operation adjoining is in progress.

It may not always be possible to operate the jacks while sinking an adjoining pier and in such cases it is advisable to use larger diameter pipe, so a man can be sent down and excavate the material as the jacking proceeds, and a positive bearing on rock can be obtained.

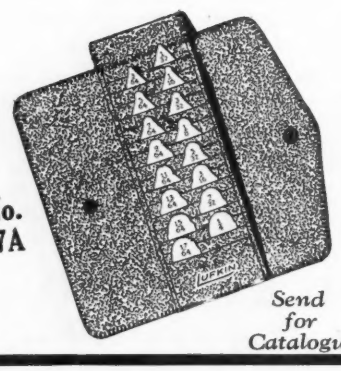
Cast iron cylinders 3 feet in diameter have been used to advantage in cases like this. They have a heavy shell, one inch in thickness or more, and stand the jacking well without any distortion.

As these cylinders have to be sunk a considerable distance through quicksand or other water bearing material, the excavation must be made under pneumatic pressure. The bottom, or working chamber, section is made 6 feet high and is provided at the bottom with a steel cutting edge, the next section above is also 6 feet high and is converted into an air lock by doors at top and bottom, and the remainder of the sections are usually 4 feet high, all sections being connected together by bolts through inside flanges.

The diameter of the cylinders being so small, there is only room for one man excavating in the bottom, one man is stationed in the air lock section locking out the excavated material in small buckets, which are hoisted to the top by the two or three top men who also operate the hydraulic jacks pushing the cylinders down.

When the cylinder is excavated and filled with concrete it is provided with a proper steel grillage at the top, which after being wedged up under the old wall or footing is finally encased in concrete.

Operations of this kind are naturally slow and, therefore, whenever it is possible, underpinning of adjoining buildings are usually started even before the old buildings are wrecked, so the foundations for the new building can start as soon as the site is cleared.



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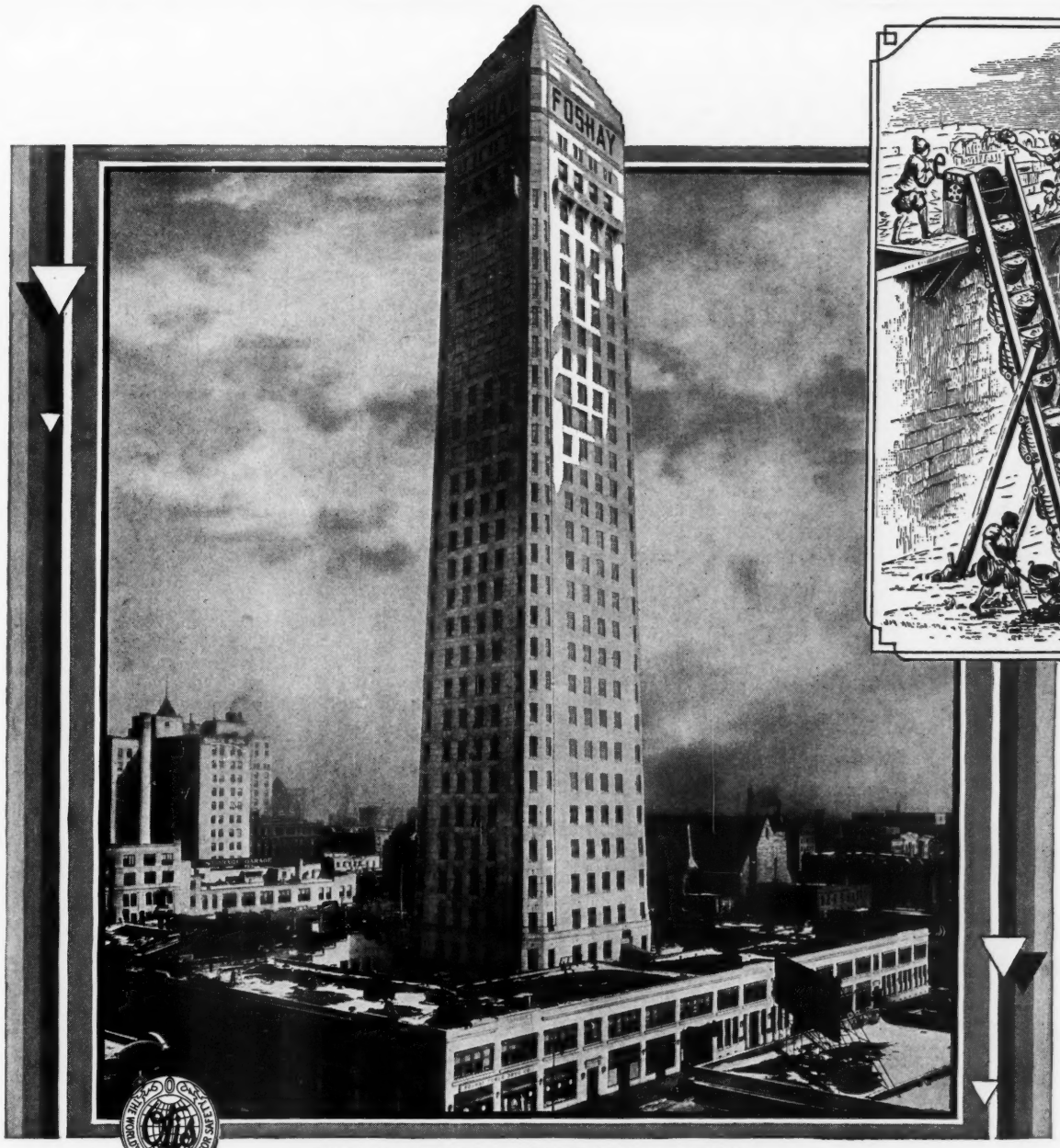

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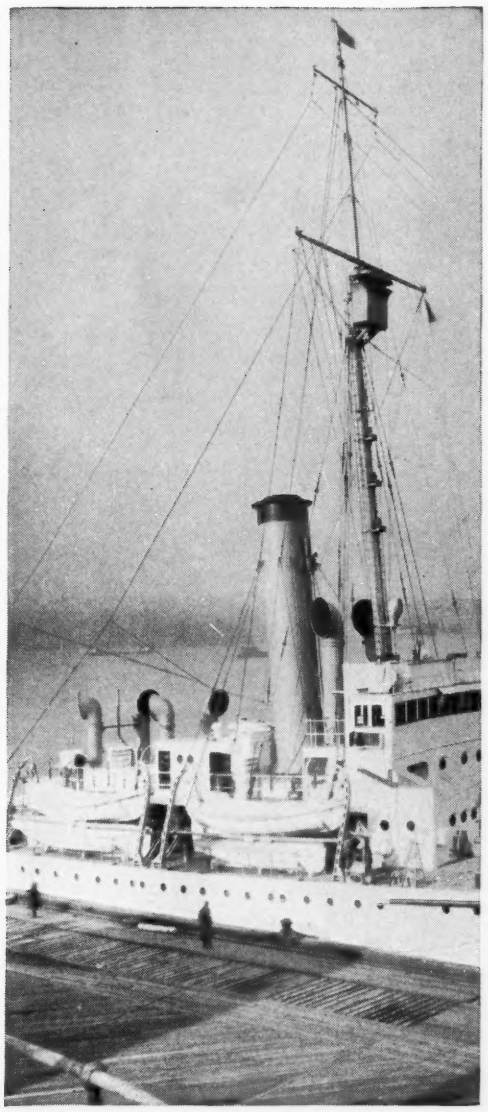

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A SCORE of carefree Coast Guard sailors, and with them a Westinghouse man from the Boston Office, headed in a "bum boat" for the cutter Chelan peacefully at anchor in the harbor of Hamilton, Bermuda Islands.

It had been an exciting shakedown test-cruise. The Westinghouse turbine, generator, motor and condensers had functioned perfectly, the sea had yielded up its bag of tricks, the Bermudas had fascinated every soul. And soon they would be bound for home.

But fate held new experiences in store. Five hundred miles off the Azores, the Newport, New York State training ship, had lost her propeller. The Chelan was called to the rescue. And with her, of course, went the Westinghouse man.

Three days at top speed on tropical waters, the excitement of rescuing a helpless crew, twelve days at a lazy towing speed, men overboard and a rescue at sea — thrills like those come to many Westinghouse men in line with their work at electrifying the world.

For Westinghouse, in a commanding position in electrical development, enters every field of industry where electricity is or may be employed. And Westinghouse men get a taste of every brand of human activity.

Westinghouse

WHAT
YOUNGER COLLEGE
MEN
ARE DOING
WITH
WESTINGHOUSE

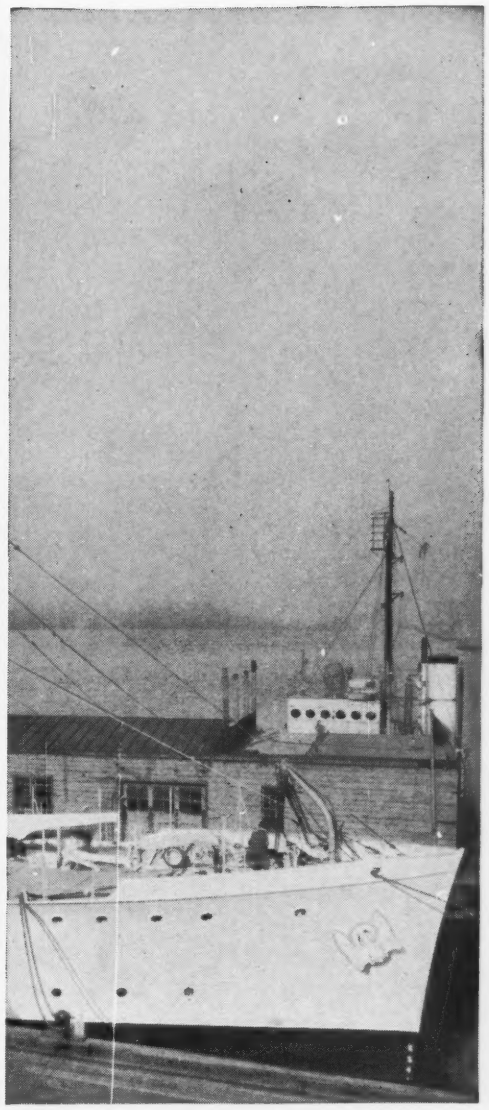
M. D. ROSS
Generator Design
University Toronto, '22

R. A. ALLEN
Headquarters Sales
Alabama Polytechnic Institute '24

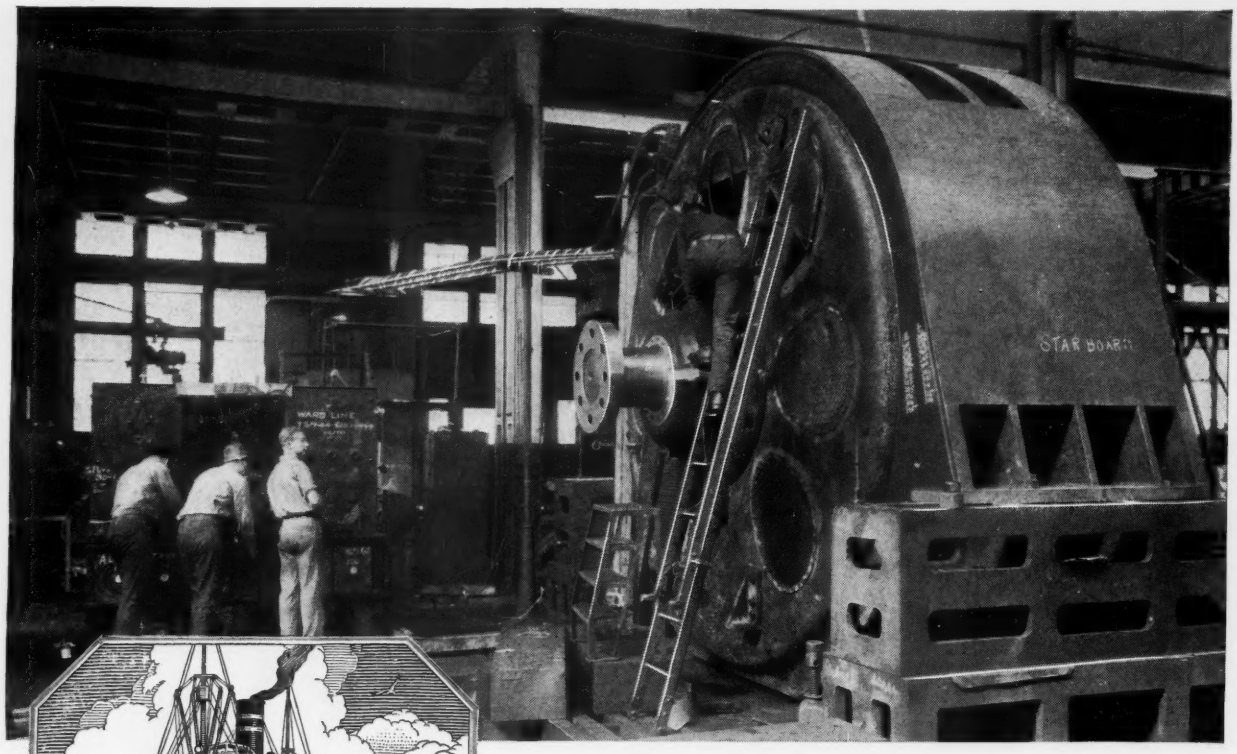
W. SCHAELCHLIN
Propulsion Control Engineer
State College '19
Zuerich, Switzerland

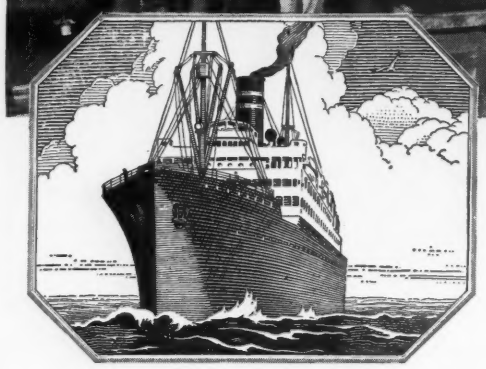
H. R. GOSS
Motor Design
University Minnesota, '20

C. M. WILLIAMS
Auxiliary Switching Design
University Illinois, '21



The Chelan, like four other Coast Guard Cutters recently completed, is equipped with Westinghouse turbine electric drive.





A Trial Trip on Test

GENERAL ELECTRIC is constructing and testing four synchronous marine motors and other electric equipment for the two new $5,500,000 Ward liners to Cuba.

Long before the maiden voyage, an earlier voyage, in effect, takes place in the G-E plant, where each motor is subjected to tests approximating and often exceeding actual service conditions that may be met on the seas.

Experienced as well as recruit Test men carefully note the responses of the big synchronous motors to saturation, synchronous impedance, core losses, phase characteristics, heat runs, static impedance, voltage wave forms, and high-potential tests.

The testing of synchronous marine motors is but one of the aspects of the electrical industry in which college-trained men who come to General Electric every year are engaged.

JOIN US IN THE GENERAL ELECTRIC HOUR, BROADCAST EVERY SATURDAY AT 9 P.M., E.S.T. ON A NATION-WIDE N.B.C. NETWORK

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

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